STUDY OF NITRATES IN THE GROUND WATER OF THE CHICO AREA BUTTE COUNTY

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State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Northern District

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Appreciation is also extended to the many area residents who allowed us to sample and measure their wells.

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STUDY OF NITRATES IN GROUND WATER OF THE CHICO AREA, BUTTE COUNTY

INTRODUCTION

Nitrate levels exceeding the 45 milligrams per liter (mg/L) drinking water standard have been found in domestic well waters in the developing area around the city of Chico. Numerous new wells have been drilled in the vicinity of Chico and many of these are used for domestic water supply. The excessive nitrate concentrations indicate that existing or potential widespread water quality problems exist in the Chico area ground water.

Area of Investigation

This ground water investigation includes an area of about 26 square miles in and adjacent to the City of Chico shown on Figure 1. Residential, commercial, and industrial developments are concentrated in Chico while adjacent lands are less intensely developed with agricultural and residential uses dominant. Most of the agricultural lands are orchards. As Chico has grown and expanded, agricultural lands on the city outskirts have been converted to urban uses.

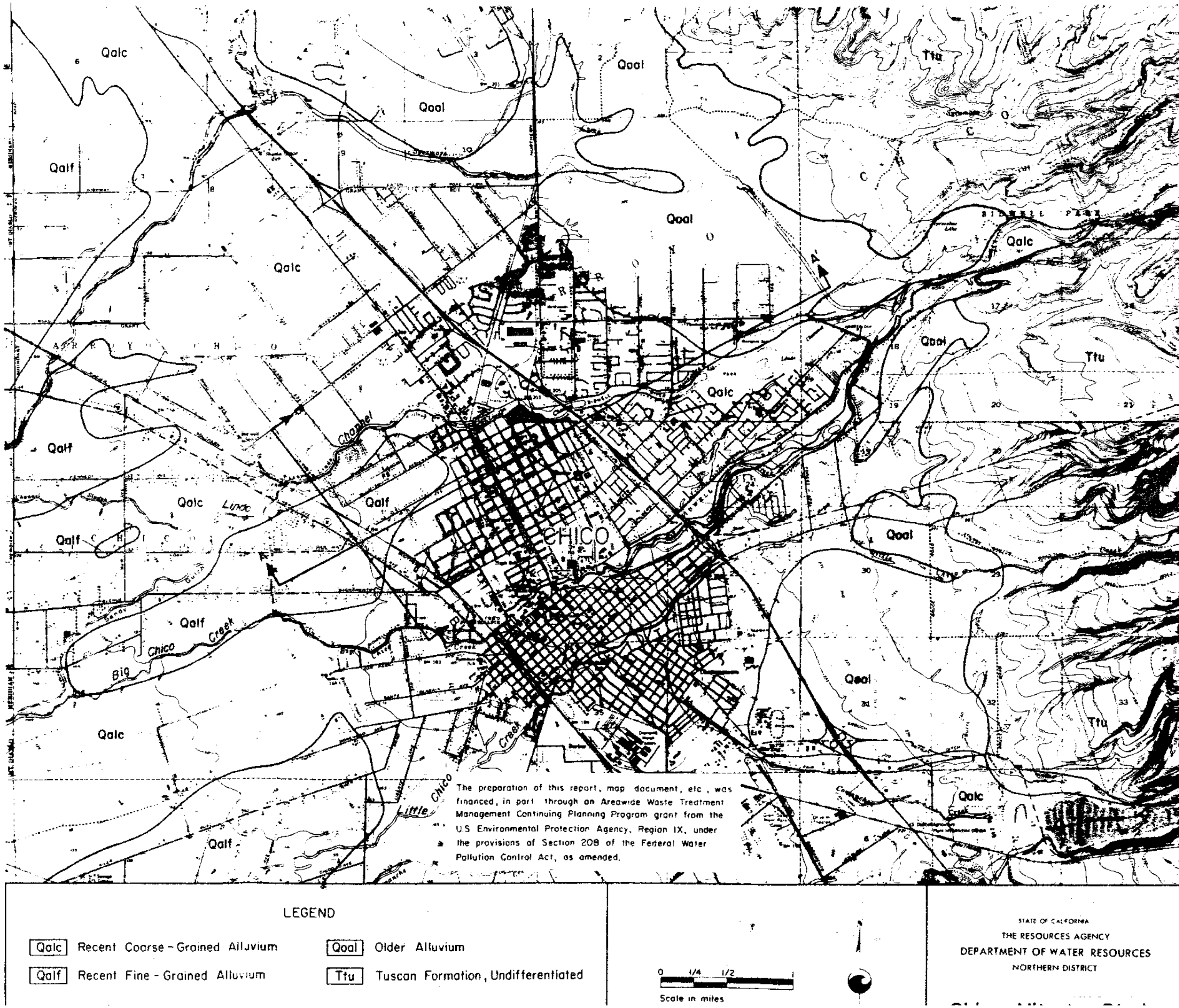
Most of the area is dependent on ground water for its water supply. Although California Water Service Company provides water throughout much of the area, numerous private wells are in use.

Most of Chico is sewered and the City operates a sewage treatment plant that disposes of its treated wastes southwest of the study area. However, numerous individual disposal systems are in use in the area which return domestic wastes to a shallow ground water zone. There are also more than 40 known drainage wells that return surface water to the shallow ground water zone. Drainage wells have generally been used to dispose of unwanted street runoff in flat areas where surface water drainage systems are inadequate and runoff could accumulate and cause flooding.

Scope of Investigation

This investigation was conducted in accordance with the ground water study contract between the County of Butte and the State Department of Water Resources (DWR No. 163130) with supplemental funding from the Quality of Water Supplies Program of this Department. The Butte County funding was provided by the Environmental Protection Agency under the provisions of Section 208 of the Federal Water Pollution Control Act as amended.

This report describes the study that was conducted in three phases. The first phase included compilation and evaluation of historic data and information, updating of geologic cross sections (DWR 1974), identification of gaps in the data base, and recommendation of an appropriate program to fill the data gaps. Upon completion of the first phase, a progress report was prepared and transmitted to the County of Butte on March 10, 1983. The major data gaps


Qalc
Qoal
Qalf
Ttu
CHICO
Chico Creek
Big Chico Creek
Little Chico Creek
Lindo Channel
T.22N.
T.21N.
The preparation of this report, map document, etc., was financed, in part through an Areawide Waste Treatment Management Continuing Planning Program grant from the U.S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended.
LEGEND
Qalc Recent Coarse-Grained Alluvium
Qalf Recent Fine-Grained Alluvium
Qoal Older Alluvium
Ttu Tuscan Formation, Undifferentiated
0 1/4 1/2 1
Scale in miles
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identified in this report were the lack of water level measurements and quality data in the shallow and intermediate water bearing zones in the Chico area.

The second phase of the study was the implementation of the program approved to fill the data gaps. Upon completion of this phase data summaries were transmitted to the county on August 5, 1983. The third phase included the integration and evaluation of data developed during the first two phases of the study and drafting of a report in September 1983. The report included discussions of geology, hydrology, water quality, and nitrate sources. The report also contained the data developed and recommendations of actions that could ameliorate the nitrate problem.

Due to time restraints associated with the Environmental Protection Agency (EPA) funding the field investigation for this study was limited to the spring of 1983 even though annual variation in ground water conditions were expected to be significant. Following completion of the original contract an extension of the time limit imposed by the EPA was granted and a supplemental contract was prepared between the County of Butte and the Department of Water Resources (DWR No. 163325). In accordance with that agreement, water level measurements were made and water samples collected during November. The resultant data has been combined with the data and information developed during the previous studies and are contained in this report. The evaluations, findings, conclusions and recommendations in this report were developed from the data developed under the two contracts.

GEOLOGY

In 1974, the Department of Water Resources (DWR) summarized the geology, ground water quality, and hydrology of the Chico area in a report related to the use of drainage wells (DWR 1974). Since 1974, we have received drillers' reports (well logs) for nine new California Water Service Company wells and more than 150 private wells drilled in the vicinity of Chico. From over 500 available well logs in our files, well logs were selected in the vicinity of each of the geologic cross sections shown in the 1974 report and were field located for use in a geologic update. These data have added to our knowledge of local geologic conditions and permitted refinement of geologic cross sections.

Local Geology

The City of Chico and surrounding area is situated on Recent alluvial fan materials (Qalc and Qalf) deposited by Big Chico and Little Chico Creeks (Figure 1). To the north and southeast of the city, older alluvial materials are exposed which are distinguished from the younger fan deposits by being more consolidated, cemented, and at depth containing much more clay. Surface soils which have formed on the older alluvium are gravelly and their topographic position is somewhat elevated above the Recent fan. In this report this material is called older alluvium (Qoal), but it also includes a unit called fanglomerate, a term used to denote alluvial fan materials which have been cemented.

Both the Recent and older alluvial materials have been derived from the Tuscan Formation which forms the hills east of Chico. The Tuscan Formation contains volcanic sediments and mudflows which extend westward into the valley beneath the older alluvium.

Geologic Units

There are four geologic units mapped in the study area. These units are delineated in Figure 1 and described in Table 1. They include the Tuscan Formation (Ttu), older alluvium (Qoal), Recent coarse-grained alluvium (Qalc), and Recent fine-grained alluvium (Qalf).

Tuscan Formation

The uppermost surface of the Tuscan Formation east of Chico forms a topographic plateau deeply dissected by westerly-draining streams. The low regional dip is toward the southwest.

The Tuscan Formation is made up of tuff-breccia, lapilli tuff, and sedimentary rocks containing volcanic debris. Locally it is overlain by thin andesite and basalt flows. The uppermost bed is a massive 30 to 150 foot thick tuff-breccia unit. Beds of volcanic sediments are found throughout the Tuscan. They are made up of cobble and boulder conglomerate, siltstone, and coarse sand layers up to 50 feet thick. Well log information indicates these beds extend as far west as the Sacramento River. In the Chico area the top of the formation

TABLE 1. GEOLOGIC UNITS IN THE CHICO AREA*

Geologic Unit	Lithology	Permeability	Water-Yielding Characteristics
Recent fine-grained alluvium (Qaif)	Unconsolidated fine sand, silt, and clay	Moderate	Moderate recharge potential to shallow zones. Not generally tapped by wells.
Recent coarse-grained alluvium (Qalc)	Unconsolidated silt, sand gravel, and cobbles	Moderate to high	Water yield to wells is limited by thickness. Main recharge area for shallow and intermediate aquifer zones. Not generally tapped by wells.
Older alluvium (Qoal) (Fanglomerate unit and older alluvium unit)	Hard andesitic cobble and boulders in a reddish-brown clay-cemented matrix. Some lenses of loose sand and gravel; occasional clay beds.	Variable but generally low	Variable yield to wells. Downward movement of water is restricted by clay layers.
Tuscan Formation (Ttu)	Breccia, tuff and volcanic sediments	High in sand and gravel material and very low in clay, tuff and and mudflow material	High yields from deep wells that tap coarse sedimentary material. Recharge mainly along streams in the foothills.

*Listed with more recent formation first.

occurs at a depth of more than 400 feet within five miles of the eastern foothills.

Older Alluvium

The older alluvium shown on the geologic map includes both fanglomerate and older fan deposits. It is exposed in stream cuts and makes up the gently sloping plain that extends southwestward from the edge of the hills to the vicinity of U. S. Highway 99E.

Recent Fine-Grained Alluvium

There are patches of Recent fine-grained alluvium west and northwest of Chico. This depositional unit was probably formed as a result of flooding and ponding in overbank areas between streams. It consists of unconsolidated sand, silt, and clay deposits less than 50 feet thick. Drillers' logs show it contains gravelly lenses and locally overlies Recent coarse-grained alluvium.

The fanglomerate consists of well cemented cobbles and boulders with a sandy clay matrix. Drillers' logs indicate there are 3 to 4 beds of fanglomerate, each ranging from 25 to 50 feet thick, separated by clay beds. The other fan deposits are slightly less consolidated and consists of gravelly clay with moderately consolidated clay, silt, and sand beds.

Recent Coarse-Grained Alluvium

The deposits mapped as Recent coarse-grained alluvium make up the nearly flat plain beneath the main part of Chico. The unit consists of unconsolidated cobbles, gravel and sand, and minor amounts of clay, with gravel and cobbles predominating. It thickens from east to west except locally where streams have eroded to the underlying older alluvium. Drillers' logs show it averages 40 to 50 feet thick in the study area.

HYDROLOGY

In the Chico area most municipal and industrial water demands are met by pumping ground water. The major sources of recharge to this portion of the Sacramento Valley ground water basin are direct precipitation in the local recharge areas and flows from Big Chico Creek and Lindo channel which traverse the area.

Water Bearing Zones

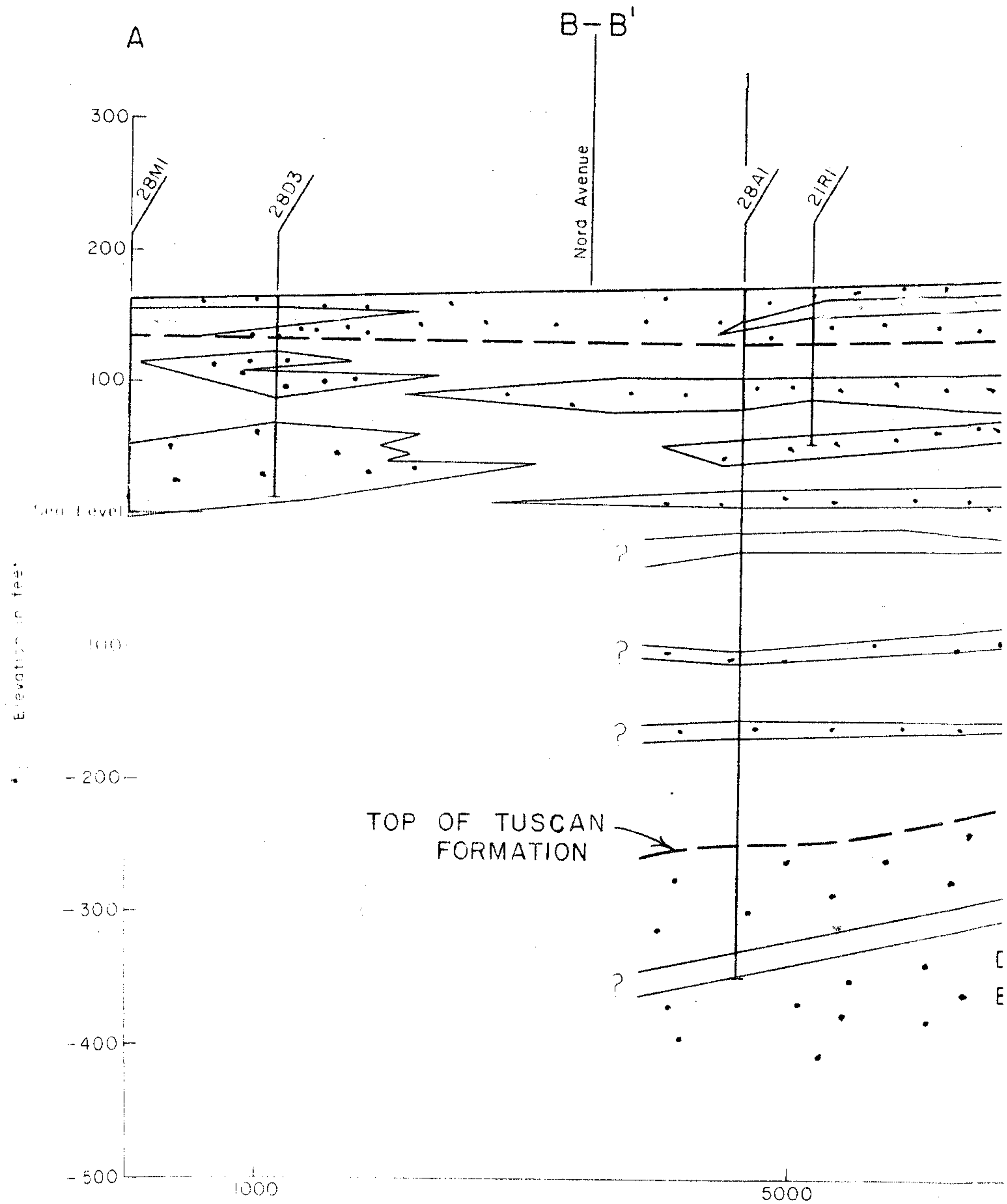
There are three water-bearing zones beneath the Chico area: shallow, intermediate, and deep. They are shown on the hydrogeologic cross-sections (Figures 2 and 3) and their recharge areas are shown in Figure 4.

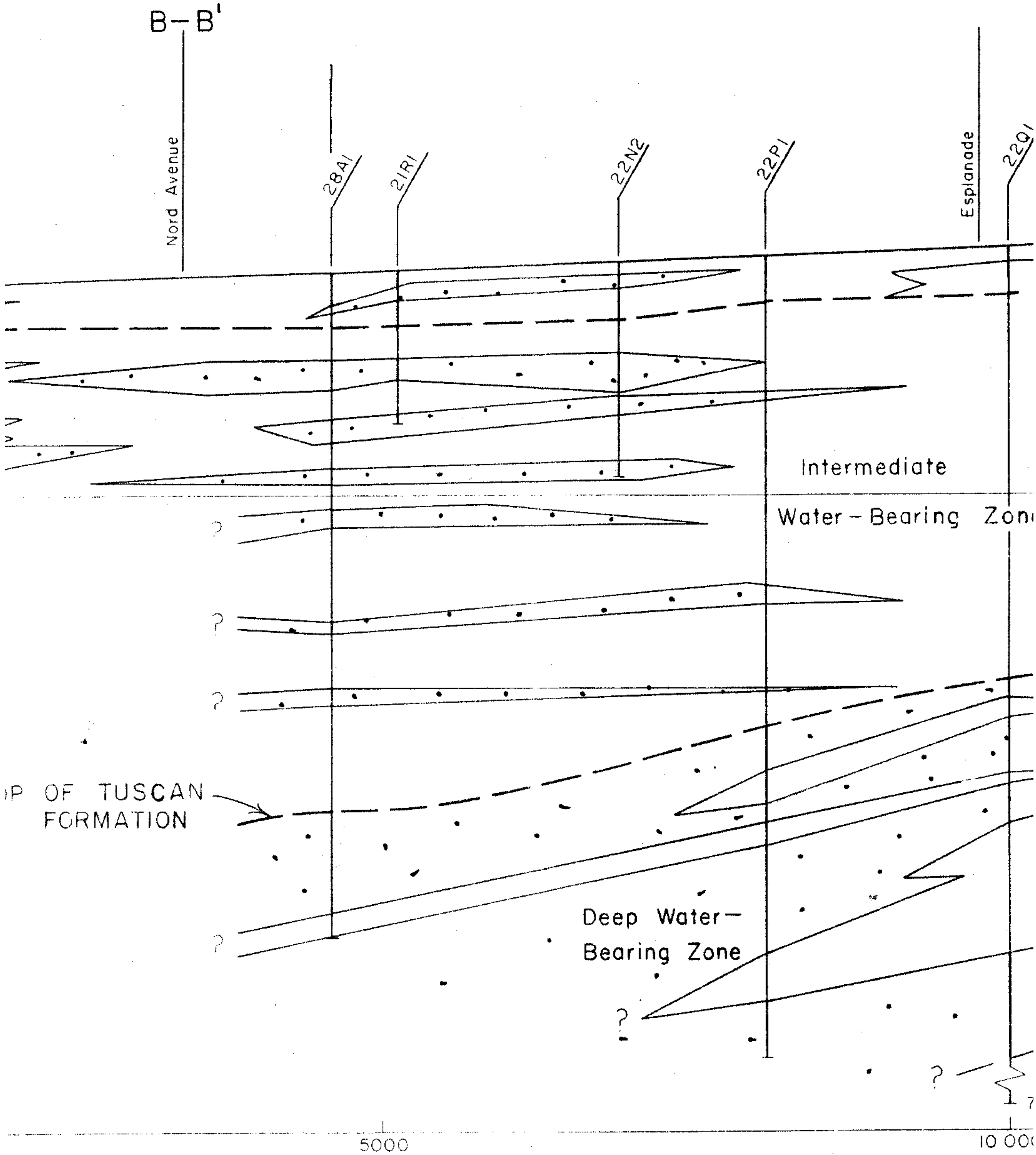
The shallow zone near Sections A-A' and B-B' consists of Recent alluvial material (Qalc) and (Qalf) deposited by Big Chico and Little Chico creeks. Most of the material is coarse sand and gravel. The fine-grained alluvium shown on the geologic map has not been differentiated on the cross-sections. Instead, fine-grained lenses are shown only where indicated by well logs in the shallow zone. At the U. S. Bureau of Reclamation (USBR) core hole (22N/1E-28J1-5), the shallow zone is 30 feet thick and consists of silt from 0 to 22 feet and coarse sand and gravel to 30 feet. Ground water in this zone is unconfined. Very little ground water is pumped from this zone in the eastern portion of Chico because of its limited storage; most wells seal off this zone and pump from the deeper zones. West of Chico the zone is thicker and some wells tap it for water. This zone receives its recharge directly from infiltration of precipitation, streamflow, domestic waste water from leach fields and urban runoff from drainage wells.

The intermediate water-bearing zone beneath Chico ranges in thickness from 0 to 450 feet. Beneath most of Chico it occurs at depths of 20 feet to 50 feet below ground surface. This zone is equivalent to the older alluvium. Its composition is mostly thick, clayey layers and cemented sand and gravel. In the USBR's core hole the older alluvium, from 30 feet to 444 feet, consists of the following: 12 percent clay and clayey silt, 26 percent cemented silty sand, 31 percent cemented sandy silt, 22 percent cemented gravel, and 9 percent uncemented sand, gravel, or gravelly sand. Ground water occurs mainly in thin uncemented sand and gravel aquifers under semiconfined conditions.

This zone receives recharge from streams incised in the older alluvium, through vertical leakage from the overlying saturated alluvium, and possibly subsurface inflow from the Tuscan Formation. The older alluvium appears to have limited vertical permeability due to cementation of the rock matrix. As a result, recharge is somewhat restricted in the outcrop area.

The deep zone aquifers are thick beds of black sand and/or coarse- grained gravel of the Tuscan Formation confined by the less permeable clay, tuff, and mudflow layers. The highly permeable volcanic sediments yield large amounts of water to deep irrigation and municipal wells. This zone is recharged mainly by streams that drain the foothill area east of Chico.


A
B-B'
300
200
100
Sea Level
-100
-200
-300
-400
-500
Elevation in feet
28M1
28D3
Nord Avenue
28A1
21R1
?
TOP OF TUSCAN FORMATION
1000
5000


B—B'
Nord Avenue
28A1
21R1
22N2
22P1
Esplanade
22Q1
Intermediate
Water-Bearing Zon
?
?
?
?
?
?
OP OF TUSCAN
FORMATION
Deep Water-
Bearing Zone
5000
10 000

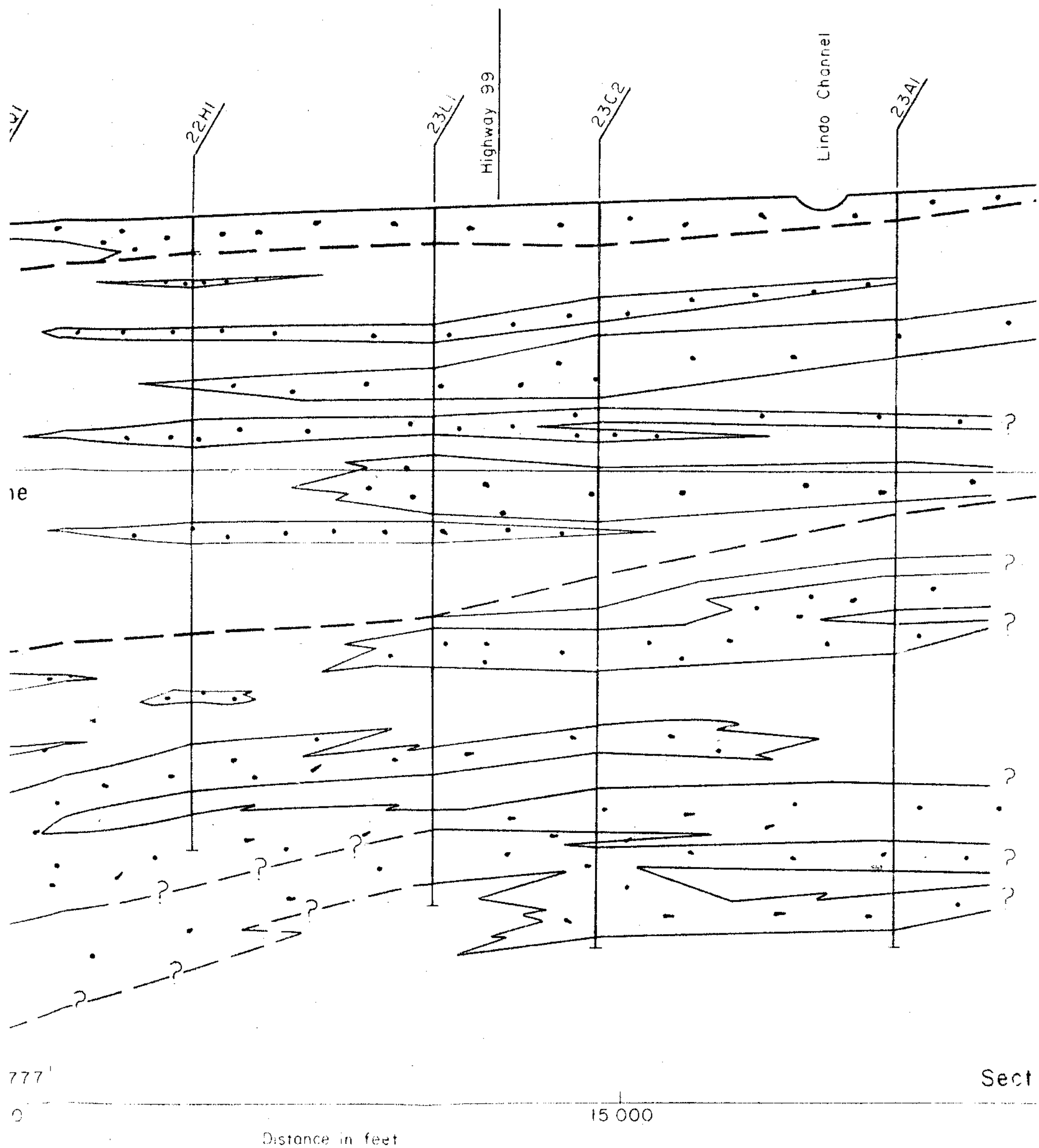
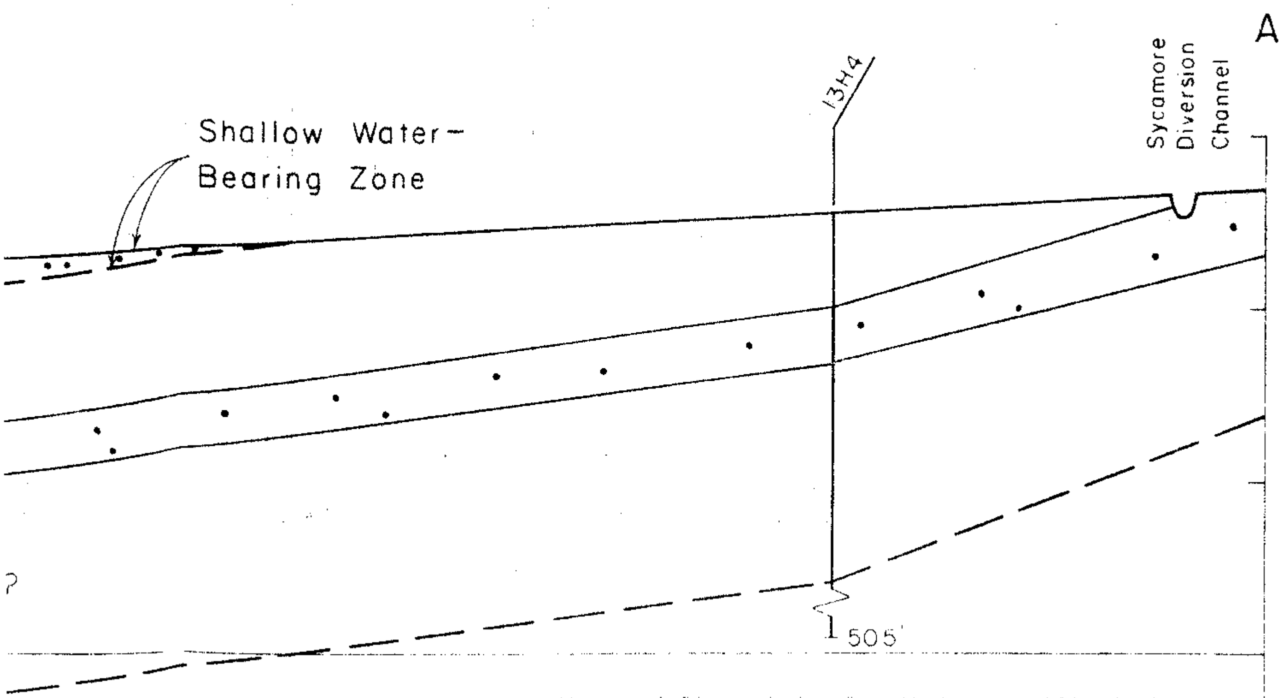

22H1
23L1
Highway 99
23C2
Lindo Channel
23A1
ne
777'
Sect
0
15 000
Distance in feet

Figure 2



LEGEND

Fine-Grained Material

Course Grained Material

28A1

Well Location and Depth

?

Geologic Contact, queried where uncertain

?

?

?

?

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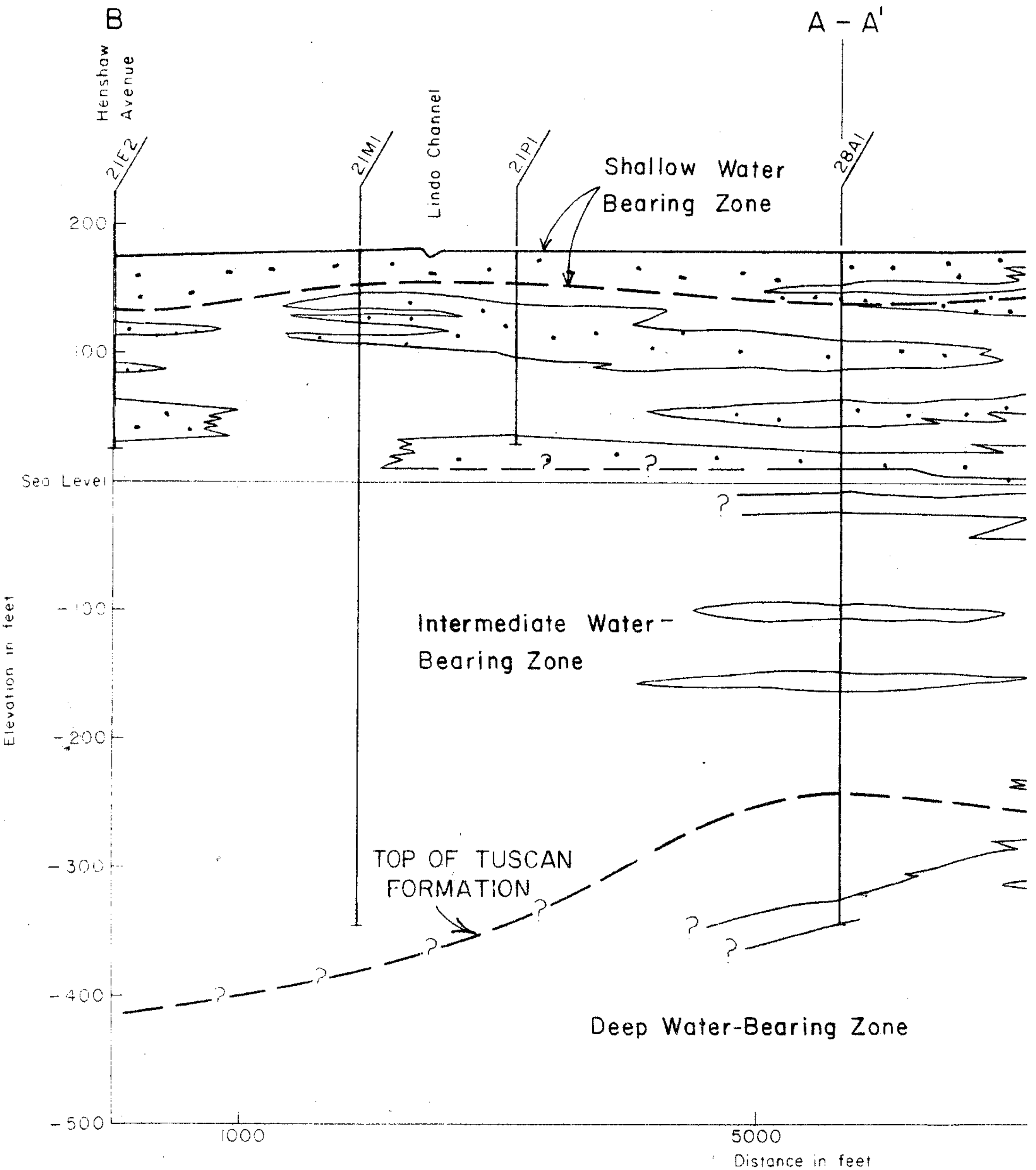
NORTHERN DISTRICT

Chico Nitrate Study Hydrogeologic Section

February 1983

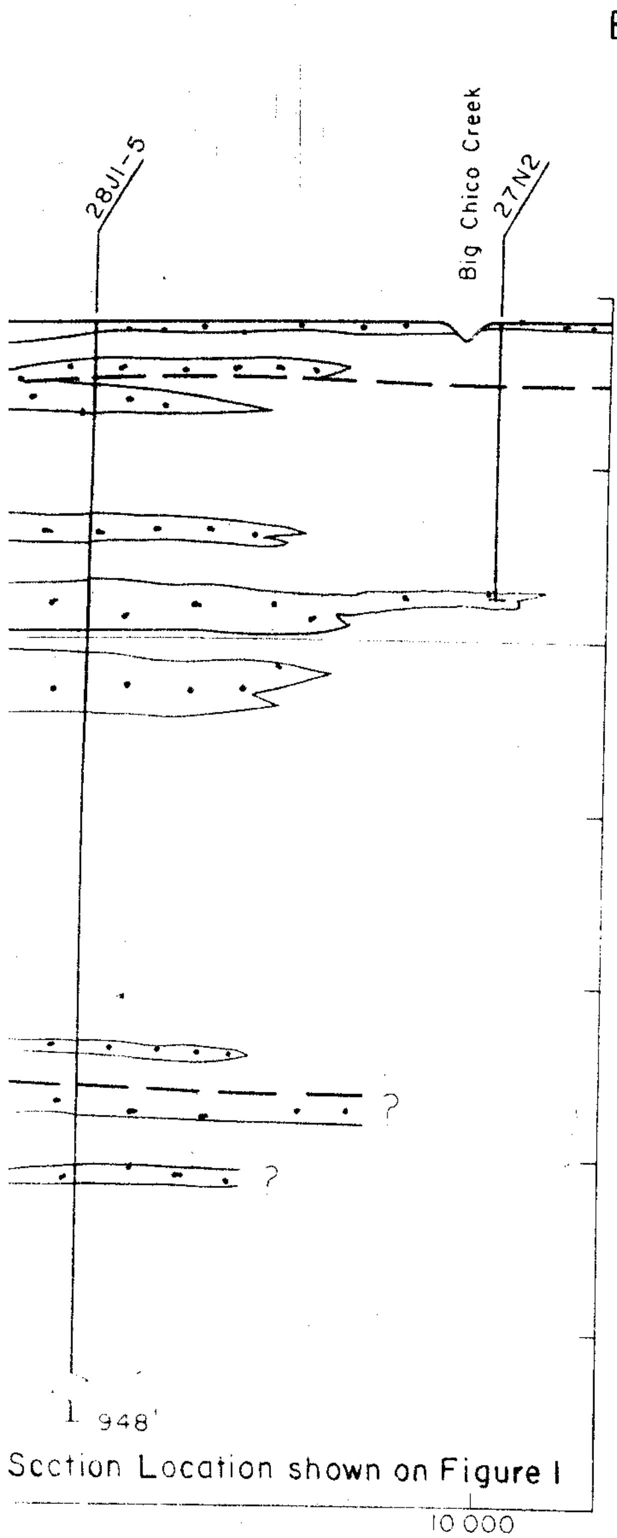
ection Location shown on Figure 1

20,000 25,000



B
A - A'
Henshaw Avenue
21E2
21M1
Lindo Channel
21P1
28A1
Shallow Water Bearing Zone
200
100
Sea Level
-100
-200
-300
-400
-500
Elevation in feet
Intermediate Water-Bearing Zone
TOP OF TUSCAN FORMATION
Deep Water-Bearing Zone
1000
5000
Distance in feet

Figure 3



LEGEND

Fine - Grained Material

Coarse - Grained Material

28A1

Well Location and Depth

—— -?- Geologic Contact, queried where uncertain.

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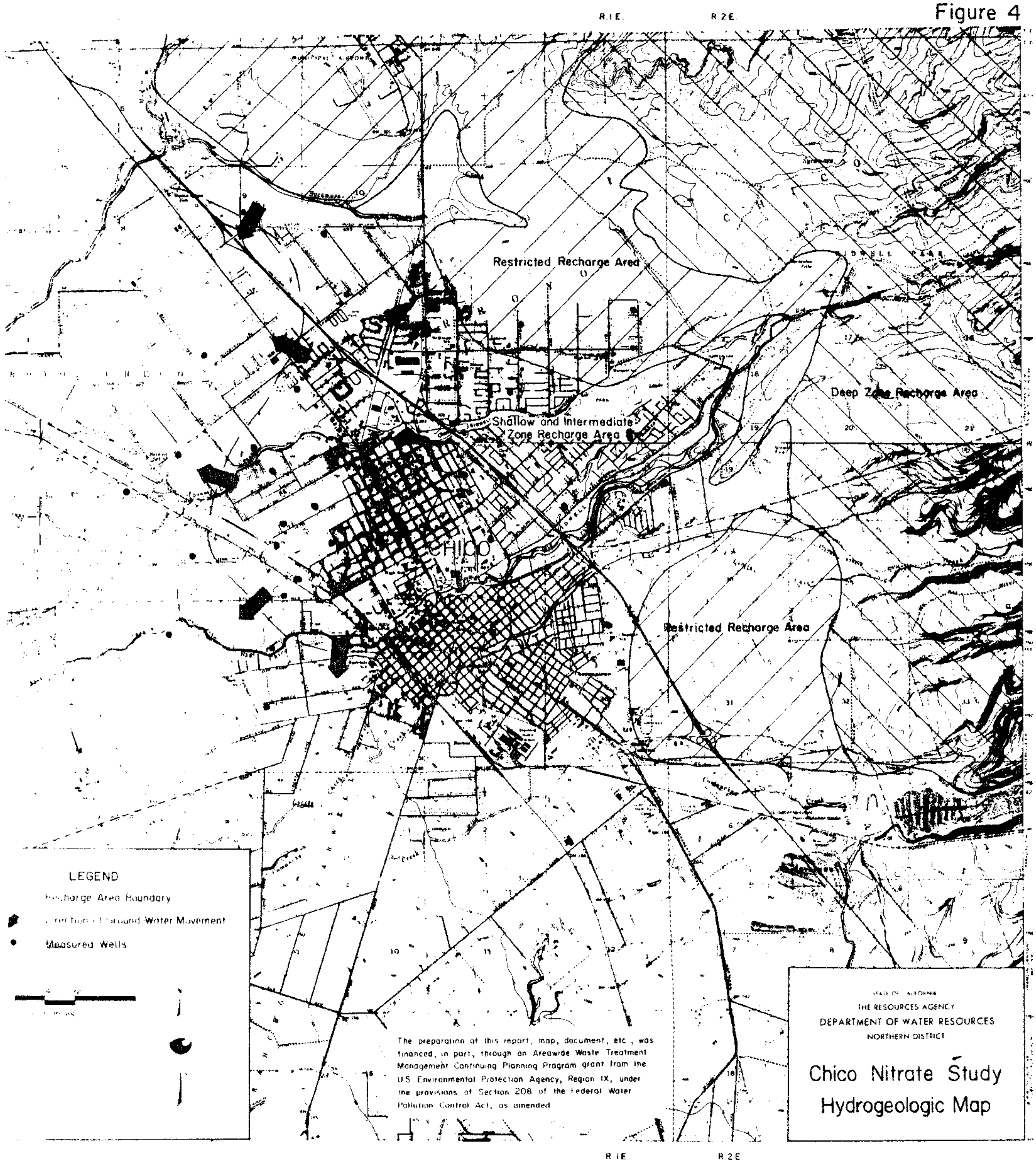
Chico Nitrate Study
Hydrogeologic Section

September 1983

Figure 4


R.1E.
R.2E.
Restricted Recharge Area
Shallow and Intermediate Zone Recharge Area
Deep Zone Recharge Area
CHICO
Restricted Recharge Area
LEGEND
Recharge Area Boundary
Direction of Ground Water Movement
Measured Wells
The preparation of this report, map, document, etc., was financed, in part, through an Areawide Waste Treatment Management Continuing Planning Program grant from the U.S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended
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NORTHERN DISTRICT
Chico Nitrate Study
Hydrogeologic Map
R.1E.
R.2E

Ground Water Levels

In the Chico area ground water level measurements show the typical pattern of high levels in the spring due to reduced uses and high rates of recharge during the winter. Lowest levels occur in the fall following the summer period of high use and limited recharge.

Hydrographs of water level measurements made at the U. S. Bureau of Reclamation multilevel piezometers (22N/1E-28J1-3) near the center of the study area are shown on Figure 5. The spring highs and fall lows for the last 10 years give a good indication of the annual fluctuation of water levels that occurs in the area. They also show the pressure differential that exists between zones.

The hydrographs show that during the spring, water tapped by 22N/1E-28J2 (24-64 feet) in the shallow zone was an average 10 feet higher than water tapped by 22N/1E-28J3 (200-279 feet) in the intermediate zone. In the fall this difference increased to about 20 feet. Water levels in the intermediate zone averaged 3 feet higher than those in the deeper zone tapped by 22N/1E-28J1 (460-559 feet). This difference remained nearly constant throughout the year.

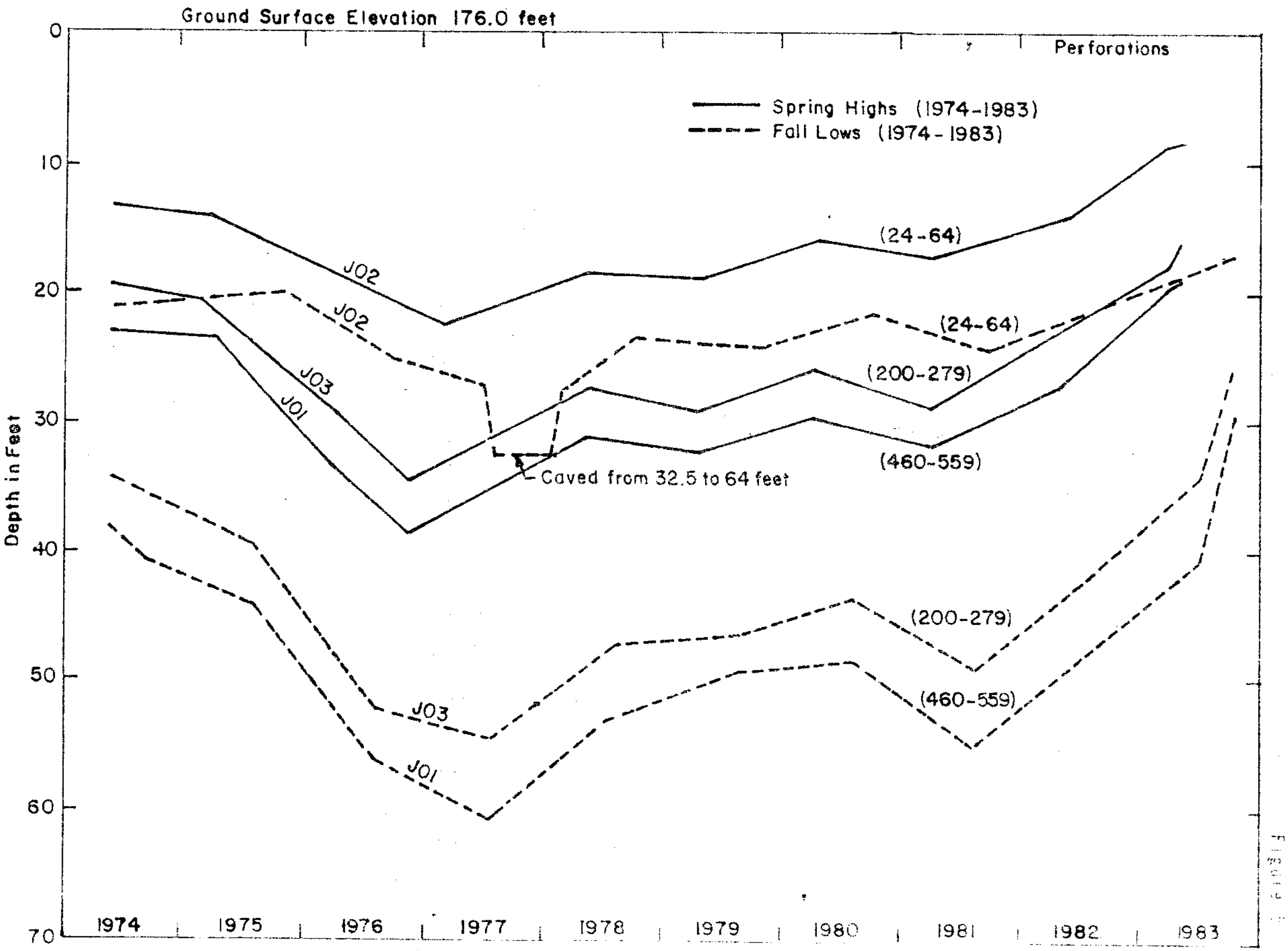
These water levels indicate the static relationship among zones near the piezometer. The relative heads could allow water to move from the shallow zone to deeper zones through openings such as those created by gravel packed or by improperly sealed or abandoned wells. The high head difference between the shallow zone and intermediate zone during the fall probably results from greater pumping in the lower zone.

Analysis of drillers' logs, electric logs, and core hole data suggests that within zones there are sections of material with low permeability. However, lenses of courser material in these sections transmit water freely and can contribute to vertical leakage between zones.

The water levels measured during this study are shown in Table 2. Where adjacent wells were of different depths, the water level in the deeper well was lower than the level in the shallower well indicating that a positive downward hydraulic gradient exists. This relationship is the same as shown in the piezometer levels and is probably prevalent throughout the area.

Ground Water Movement

Water level contours plotted for the 10-year period from 1957-1967 show the general pattern and direction of movement depicted in Figure 4. More recent measurements obtained from the California Water Service Company provided a basis for spring and fall contours shown on Figures 6 and 7 for the deep zone. Ground water level measurements made as part of this investigation provided a basis for the ground water contours in the shallower zones (Figures 8 and 9). Most of the shallow wells in the Chico area extend through the shallow zone and into upper portions of the intermediate zone. As a result measurements from these wells represent a composite of levels in the shallow and intermediate zones.



Hydrograph of U.S.B.R. Piezometer 22N01E-28J

TABLE 2
CHICO NITRATE STUDY
WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
21N/1E- 1G2	127	5/19/83	12.7	183.3	5/19/83	-	7.1	256	2	12
		11/30/83	21.2	174.8	11/30/83	14	7.1	250	2	12
21N/1E- 2C2	126	5/11/83	17.3	168.7	5/13/83	-	6.9	426	24	24
		11/30/83	24.0	162.0	11/30/83	15.5	6.8	440	19	24
21N/1E- 2F4	90	5/13/83	15.7	165.3	5/13/83	-	7.1	433	8	71
		11/30/83	21.6	159.4	11/30/83	10	7.0	420	8	49
21N/1E- 3A3	-	5/13/83	14.5	162.5	5/13/83	-	7.1	423	12	22
21N/1E- 3H5	150	12/ 7/83	19.7	152.3	12/ 7/83	13.5	6.9	950	67	66
21N/1E- 4G2	178±	5/13/83	9.6	149.4	5/13/83	-	7.1	320	12	21
		11/30/83	16.0	143.0	11/30/83	9.5	7.1	345	12	20
21N/1E- 9G4	106	5/13/83	13.0	143.0	5/13/83	-	7.2	392	8	30
		11/30/83	20.8	135.2	11/30/83	11.5	7.0	408	8	31
21N/1E-10B1	275±	5/13/83	17.7	150.3	5/13/83	-	7.1	282	2	17
21N/1E-10B2	70±	11/30/83	19.7	148.3	11/30/83	14	6.8	270	8	9.7
21N/2E- 6C1	137	4/20/83	14.5	195.5	4/20/83	-	6.9	181	-	-
		11/30/83	18.3	191.7	11/30/83	10.5	6.8	158	-	-
22N/1E- 2R1	110	10/ 3/83	65.0	153.0	-	-	-	-	-	-
22N/1E- 7B2	135	2/15/83	9.5	151.5	2/16/83	-	7.1	547	-	-
22N/1E- 8L1	230	5/12/83	7.6	155.4	5/12/83	-	7.1	514	30	24
22N/1E- 8R1	150±	11/22/83	15.4	148.6	11/22/83	14	7.3	500	19	24
22N/1E- 9G1	155	2/16/83	-	-	2/16/83	-	7.2	757	22	27
22N/1E- 9G2	145	2/17/83	18.4	154.6	2/17/83	-	7.3	534	29	34

TABLE 2

CHICO NITRATE STUDY

WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
22N/1E- 9G2	145	11/18/83	21.5	151.5	11/18/83	14.5	7.2	608	30	36
22N/1E- 9J2	165	5/12/83	14.4	163.6	5/12/83	-	7.1	255	3	13
		11/18/83	22.0	156.0	11/18/83	14	7.1	260	3	15
22N/1E- 9L1	169	2/15/83	14.0	155.0	2/16/83	-	7.1	680	34	35
		11/18/83	17.7	151.3	11/18/83	13	7.1	740	34	37
22N/1E-10K2	98	5/19/83	17.1	169.9	5/19/83	-	7.2	508	25	42
		11/18/83	28.1	158.9	--	-	-	-	-	-
22N/1E-10K3	140	11/18/83	-	-	11/18/83	12	7.1	578	17	53
22N/1E-10M2	125	2/15/83	22.2	158.8	2/16/83	-	7.1	1280	26	71
		11/18/83	24.1	156.9	11/18/83	14.5	7.1	1040	16	44
22N/1E-10P1	70	--	-	-	11/18/83	16.5	6.9	860	77	44
22N/1E-13D1	140	11/18/83	66.0	159.0	12/ 7/83	13	6.9	205	5	9.7
22N/1E-13G3	200	2/16/83	-	-	2/16/83	-	6.8	225	9	18
22N/1E-13G4	130	--	-	-	12/ 7/83	18	7.0	360	19	42
22N/1E-14F1	-	5/19/83	29.8	175.2	--	-	-	-	-	-
22N/1E-14H1	200	--	-	-	2/15/83	-	7.3	315	13	28
		--	-	-	11/18/83	14	7.1	320	12	27
22N/1E-14H2	130	5/13/83	-	-	5/13/83	-	7.3	316	-	-
22N/1E-14K1	178	--	-	-	12/13/83	14	7.0	600	26	76
22N/1E-14Q1	110±	5/13/83	25.7	191.3	5/13/83	-	7.1	425	13	53
22N/1E-15A1	185	--	-	-	5/19/83	-	6.9	907	60	93
		--	-	-	11/18/83	16	7.0	850	65	89

TABLE 2
CHICO NITRATE STUDY
WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
22N/1E-15C3	204	2/17/83	26.0	162	2/17/83	-	6.9	832	25	71
		11/18/83	29.9	158.1	11/18/83	16	7.1	845	24	62
22N/1E-15F1	152	12/13/83	28.0	157	12/13/83	14	7.0	620	20	39
22N/1E-15Q1	180	12/13/83	28.3	176.7	12/13/83	9.5	6.9	460	15	34
22N/1E-16B1	180±	12/13/83	20.0	156	12/13/83	10.5	7.0	760	24	71
22N/1E-16E1	145	--	-	-	11/22/83	13	7.4	323	12	0.0
22N/1E-16K1	-	5/12/83	18.0	161	5/12/83	-	7.0	475	18	40
22N/1E-16K2	150	11/22/83	26.7	151.3	11/22/83	11.5	6.9	380	15	35
22N/1E/16G2	130	--	-	-	11/22/83	13	7.0	600	22	62
22N/1E-16M1	160	2/17/83	22.8	148.2	2/17/83	-	7.2	279	8	3.5
		11/22/83	18.0	153	11/22/83	10	6.9	395	11	14
22N/1E-16R1	-	12/13/83	23.9	161.1	12/13/83	13.5	6.9	790	37	19
22N/1E-17M1	140	5/12/83	3.6	151.4	5/12/83	-	7.1	755	23	49
		11/22/83	13.1	141.9	11/22/83	12	6.9	520	17	33
22N/1E-17N2	120	5/12/83	1.9	150.1	5/12/83	-	7.3	367	14	15
		11/22/83	11.0	141	11/22/83	16	7.1	360	-	-
22N/1E-17P1	140	2/17/83	13.6	146.4	2/17/83	-	7.2	333	9	12
		11/22/83	17.4	142.6	11/22/83	10.5	7.1	375	10	14
22N/1E-20K1	110	5/12/83	12.9	152.6	5/12/83	-	7.1	337	12	13
		11/22/83	23.6	141.9	11/22/83	10	6.9	630	27	43
22N/1E-21B1	95	4/19/83	18.6	160.4	4/19/83	-	7.1	1755	-	-
		11/22/83	26.2	152.8	11/22/83	16.5	6.9	750	-	-

TABLE 2

CHICO NITRATE STUDY

WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
22N/1E-21E2	150	4/19/83	15.5	154.8	4/19/83	--	7.3	356	-	-
		11/22/83	24.0	146.3	11/22/83	14.5	6.9	380	-	-
22N/1E-21F1	167	5/12/83	17.2	142	2/8/83	-	7.1	203	6	2.3
		11/22/83	25.8	149.2	11/22/83	13.5	7.0	300	-	-
22N/1E-21G1	250±	2/4/83	28.6	155.4	2/14/83	-	7.1	138	3	0.9
22N/1E-21G2	-	5/12/83	18.9	157.8	--	-	-	-	-	-
22N/1E-21P1	150	4/6/83	15.4	159.6	4/19/83	-	7.5	235	6	5.7
		11/18/83	25.3	124.7	11/18/83	14	6.8	280	8	9.7
22N/1E-21Q1	120±	12/ 7/83	24.7	153.3	12/ 7/83	13.5	7.0	500	26	53
22N/1E-22M1	60	5/12/83	17.3	167.7	--	-	-	-	-	-
		11/22/83	25.9	151.9	--	-	-	-	-	-
22N/1E-22N2	170	5/12/83	16.7	168.3	2/ 8/83	10.8	-	470	21	44
		11/18/83	25.3	159.7	11/18/83	13	6.9	495	22	44
22N/1E-23C3	43	5/19/83	14.3	192.7	--	-	-	-	-	-
		11/18/83	33.2	173.8	--	-	-	-	-	-
22N/1E-23Q1	90	5/13/83	10.1	200.9	5/13/83	-	6.9	401	20	24
		11/18/83	17.0	194	11/18/83	15.5	6.8	380	11	8
22N/1E-23Q2	86	11/18/83	30.8	182.2	--	-	-	-	-	-
22N/1E-25G1	-	5/19/83	21.2	201.8	5/19/83	-	6.9	275	9	8.0
		11/22/83	20.9	202.1	11/22/83	14	6.8	275	-	-
22N/1E-26N1	-	--	-	-	11/30/83	-	7.4	294	12	4.3
22N/1E/27L1	144	5/12/83	18.9	167.1	5/12/83	19	6.9	713	13	15

TABLE 2
CHICO NITRATE STUDY
WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
22N/1E-27L1	144	11/22/83	24.9	161.1	11/22/83	18	6.9	700	14	17
22N/1E-27N1	85	4/ 6/83	18.8	163.2	4/19/83	-	7.4	217	10	1.0
		11/30/83	26.6	155.4	11/30/83	13.5	7.1	225	10	1.6
22N/1E/28B1	125	11/18/83	19.8	158.2	11/18/83	15	7.0	950	44	106
22N/1E-28B2	193	4/19/83	17.4	162.1	4/19/83	15	7.1	378	-	-
		11/22/83	25.7	150.3	11/22/83	13	7.1	380	17	33
22N/1E/28D3	152	2/17/83	17.3	149.7	2/17/83	16.5	7.0	1300	70	150
		11/18/83	21.6	145.4	11/18/83	16.5	6.9	1200	60	164
22N/1E-28F1	305	--	-	-	12/ 7/83	16.5	7.1	1240	51	155
22N/1E-28H1	76	5/11/83	16.0	160.5	5/12/83	19	6.9	1088	32	62
		11/18/83	22.3	154.2	11/18/83	14	6.9	1100	31	58
22N/1E-28J3	279	5/--/83	18.7	157.3	--	-	-	-	-	-
		11/--/83	23.8	152.2	--	-	-	-	-	-
22N/1E-28K2	170	5/11/83	14.4	155.6	5/11/83	19	6.9	621	22	28
		11/18/83	21.9	148.1	11/18/83	16	7.0	650	22	31
22N/1E-28M1	162	--	-	-	5/19/83	-	7.1	649	25	0.0
		11/22/83	19.4	144.6	11/22/83	13	6.9	680	25	53
22N/1E-28Q1	125	2/17/83	21.5	152	2/17/83	11.8	7.4	233	9	2.1
		11/30/83	23.9	149.6	11/30/83	13	7.0	225	10	2.7
22N/1E-29G1	80±	12/13/83	19	143	12/13/83	11	7.0	1310	67	120
21N/1E-29H1	167	12/ 7/83	20.7	144.3	12/ 7/83	10.5	7.0	730	23	58
22N/1E-33B1	-	12/ 7/83	23.1	146.9	12/ 7/83	15	7.1	180	10	0.8

TABLE 2

CHICO NITRATE STUDY

WATER LEVEL MEASUREMENTS AND WATER QUALITY

STATE WELL NUMBER	DEPTH OF WELL	DATE MEASURED	DEPTH TO WATER	WATER SURFACE ELEVATION	DATE SAMPLED	TEMP. °C	pH	E.C. µmho/cm	CLORIDE mg/L	NITRATE mg/L
22N/1E-33G2	205	2/17/83	23.3	150.7	2/17/83	14.5	6.8	784	28	71
		11/30/83	24.9	149.1	11/30/83	13.5	7.0	1000	35	97
22N/1E-33J1	125±	11/30/83	23.6	149.4	11/30/83	15.5	7.0	140	16	25
22N/1E-33J2	75	--	-	-	5/11/83	-	6.9	1046	34	89
		--	-	-	11/30/83	16.5	6.8	975	9	42
22N/1E-33N2	258	11/30/83	18.2	140.8	11/30/83	16	7.1	220	9	5.8
22N/1E-33Q1	185	5/13/83	12.8	153.2	5/13/83	23.5	7.1	507	31	25
		11/30/83	20.9	145.1	11/30/83	11.5	7.0	540	31	25
22N/1E-34C1	-	12/ 7/83	18	168	12/ 7/83	14.5	7.1	205	8	2.2
22N/1E-34K1	-	5/11/83	14.1	162.9	--	-	-	-	-	-
22N/1E-34L1	127	2/17/83	17.0	156.5	2/17/83	16	7.1	564	16	13
		11/30/83	17.9	155.6	11/30/83	11.5	6.9	590	17	14
22N/1E-36C2	-	5/19/83	8.0	200.0	--	-	-	-	-	-
22N/1E-36Q1	107	--	-	-	5/13/83	18	7.1	309	3	0.0
		11/30/83	24.9	178.1	11/30/83	14.5	6.9	340	3	0.0

Figure

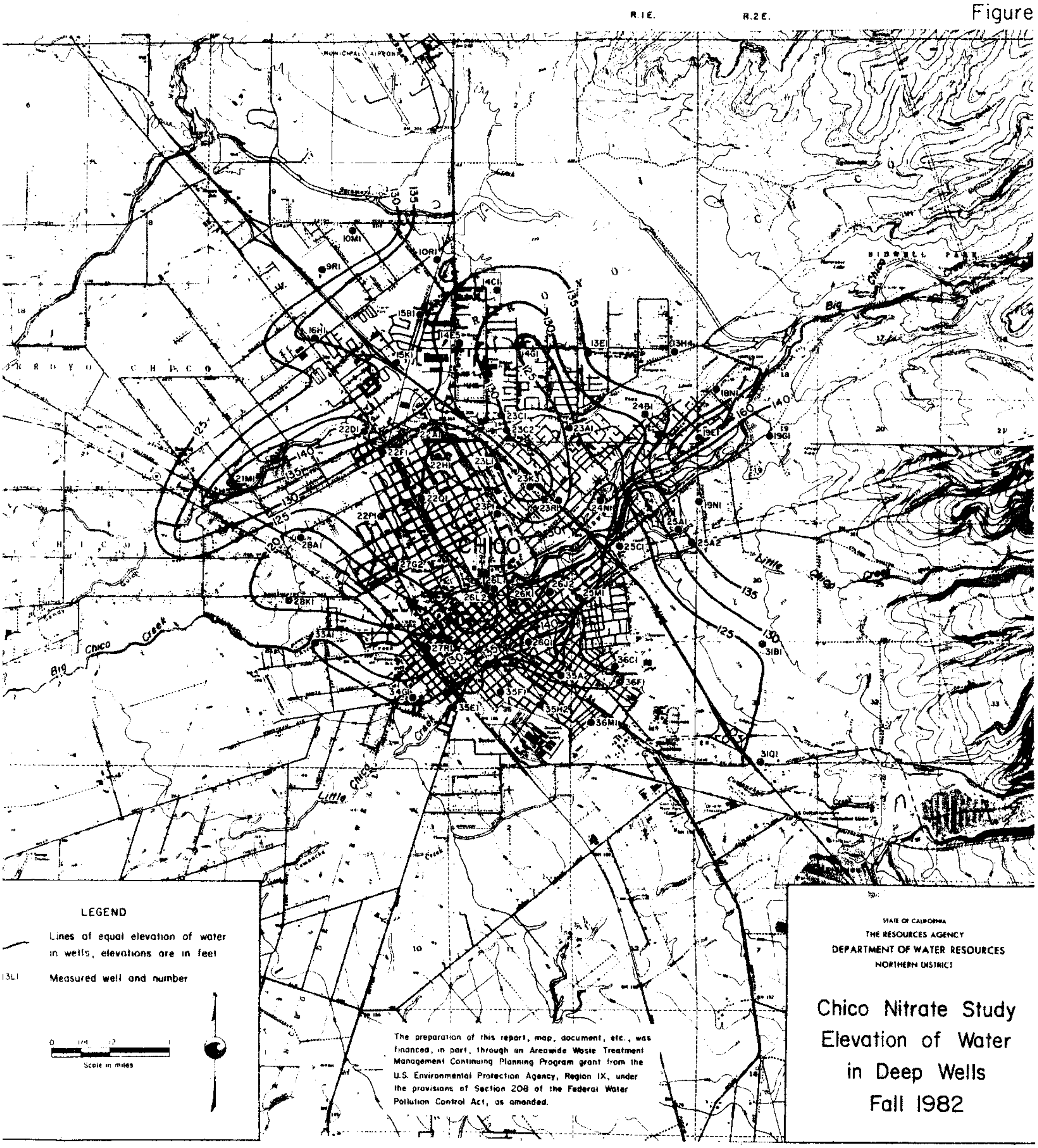
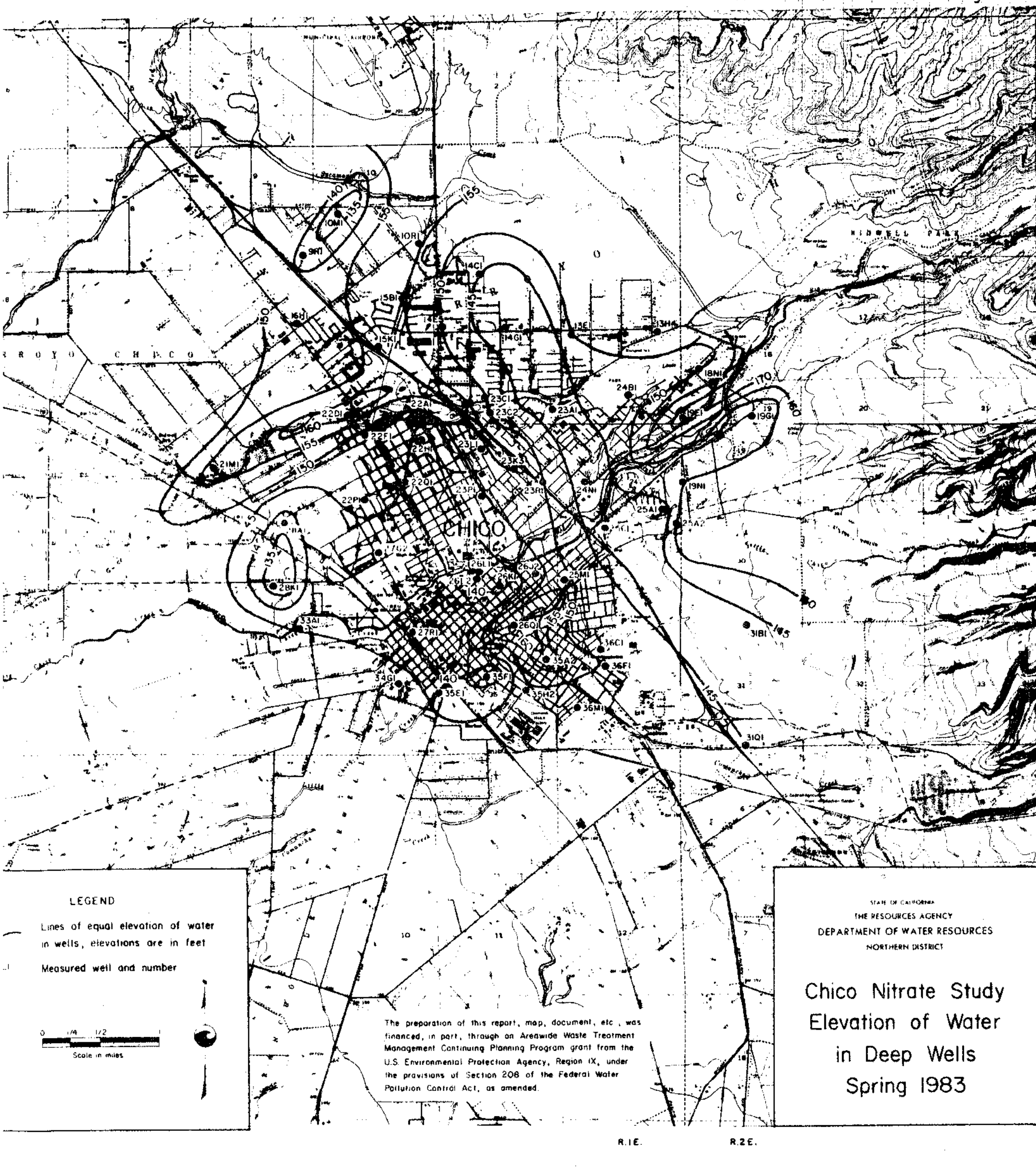
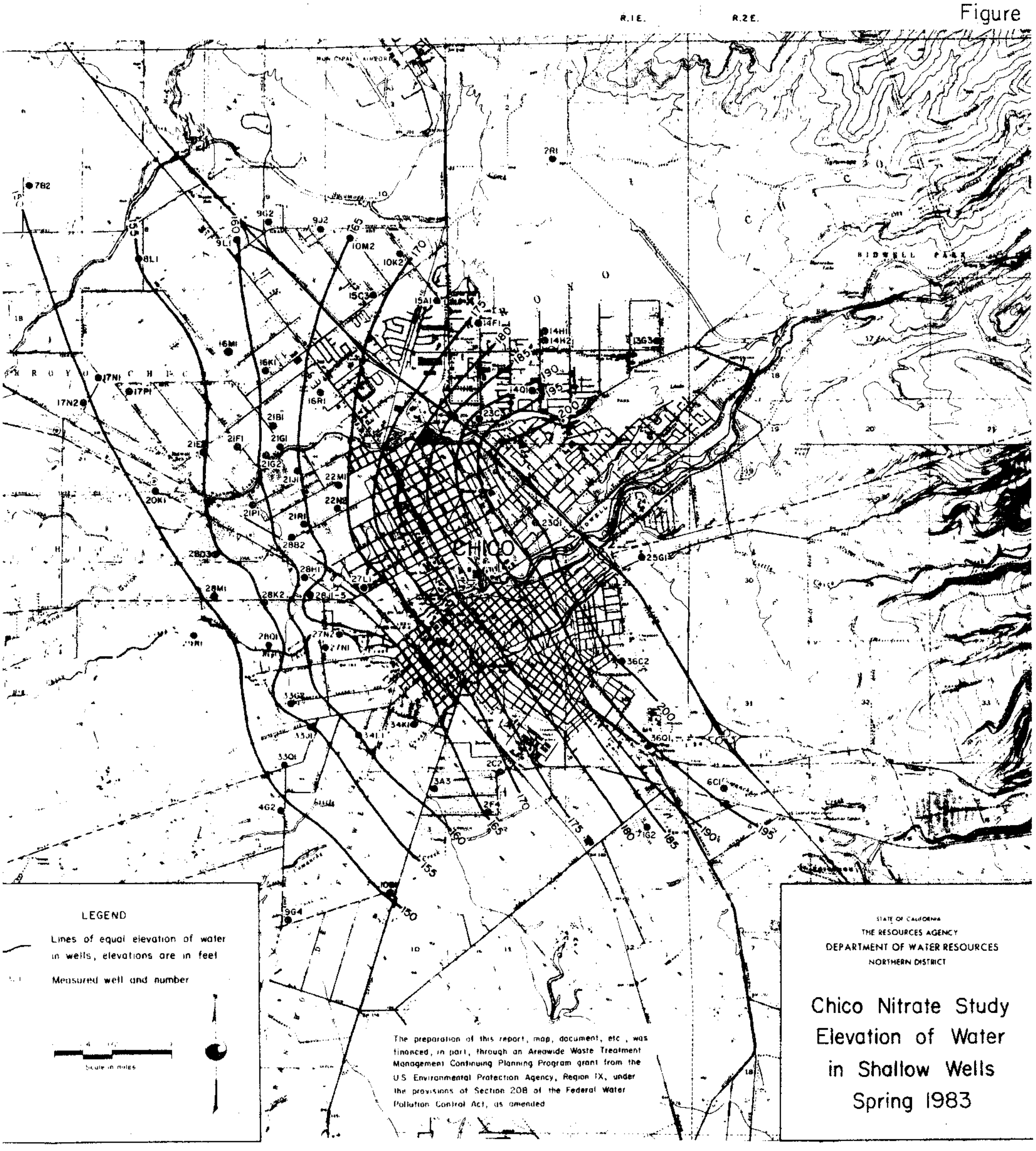

R.1E.
R.2E.
CHICO
Big Chico Creek
Little Chico Creek
LEGEND
Lines of equal elevation of water in wells, elevations are in feet
13L1 Measured well and number
Scale in miles
The preparation of this report, map, document, etc., was financed, in part, through an Areawide Waste Treatment Management Continuing Planning Program grant from the U.S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Chico Nitrate Study
Elevation of Water
in Deep Wells
Fall 1982
R.1E.
R.2E.

Figure 7



Chico Nitrate Study
Elevation of Water
in Deep Wells
Spring 1983

Figure



R.1E.
R.2E.
BIDWELL PARK
CHICO
LEGEND
Lines of equal elevation of water in wells, elevations are in feet
Measured well and number
Scale in miles
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Chico Nitrate Study
Elevation of Water
in Shallow Wells
Spring 1983
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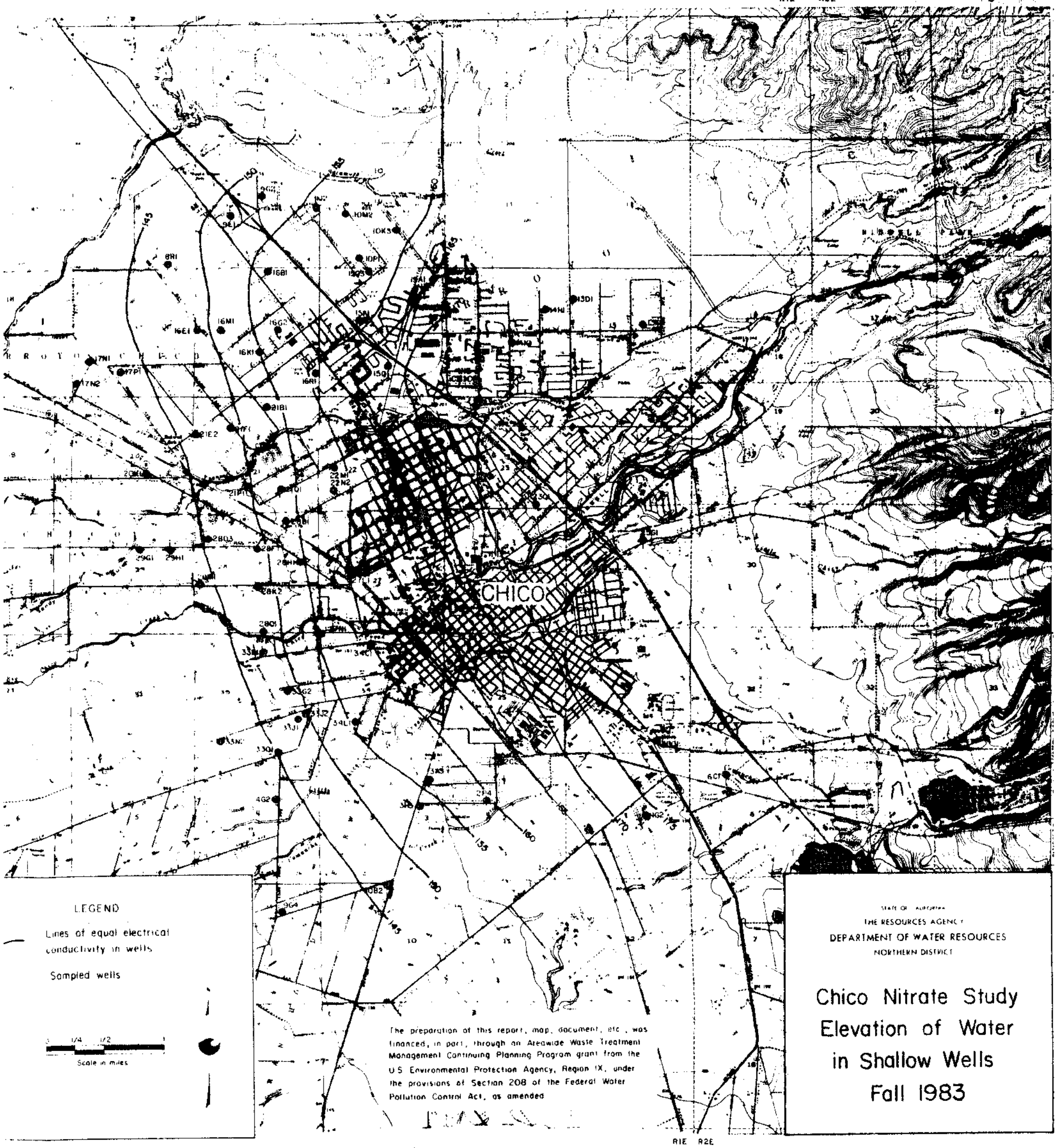
150
155
160
165
170
175
180
185
190
195
200
R.1E.
R.2E.

Figure 9


R1E R2E
CHICO
LEGEND
Lines of equal electrical conductivity in wells
Sampled wells
Scale in miles
The preparation of this report, map, document, etc., was financed, in part, through an Areawide Waste Treatment Management Continuing Planning Program grant from the U.S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Chico Nitrate Study
Elevation of Water
in Shallow Wells
Fall 1983
R1E R2E

Shallow Zones (Shallow and Intermediate Zones)

The highest ground water levels in the shallow wells during the spring of 1983 were along the base of the foothills east of Chico. As shown by the contours on Figure 8 ground waters were moving west and southwesterly through the shallower zones.

In the spring a ground water mound exists at the apex of the Chico fan under Bidwell Park. From this mound groundwaters north of Lindo Channel generally move westerly while those to the south move southwesterly.

Near the foothills the water table is quite steep having a gradient of about 25 feet per mile. In the vicinity of the Southern Pacific Railroad on the western edge of Chico the gradient decreases abruptly to about 10 feet per mile. This change is due to the greater permeability of the sediments in the southwestern portion of the study area. These more porous sediments start thickening west of the Highway 99 and form a significant part of the shallow well aquifer in that area. The clay rich sediments, whose low permeability restricts subsurface flow in the high gradient area, are an extension of the fanglomerate unit that borders the foothill.

Water levels in the shallow wells during November 1983 were found to average about 6 feet lower than in the previous spring. They showed the same general pattern of movement (Figure 9), but without the gradient change from east to west.

Deep Zone

Ground water contour maps were drawn for fall of 1982 and the spring of 1983 based on deep zone measurements provided by California Water Service Company to show direction of water movement during low and high water table conditions (Figures 6 and 7). Although some local variation exists, the general patterns of water movement were similar during the two periods.

The contours show ground water mounds where Big Chico Creek emerges from the foothills, along Lindo Channel west of the Esplanade, and near Little Chico Creek and Park Avenue. These mounds are each overlain by Recent coarse-grained alluvial deposits which are pathways for of ground water recharge.

WATER QUALITY

Ground waters underlying the City of Chico and the surrounding area are generally of good mineral quality reflecting the excellent mineral quality of the surface waters in Little Chico Creek, Big Chico Creek and Lindo Channel which provide much of the ground water recharge. Both the creek waters and ground waters are usually calcium-magnesium bicarbonate in character. The total dissolved solids content of the surface waters seldom exceeds 150 milligrams per liter (mg/L) while the concentration in the ground waters is usually less than 300 mg/L. Poorer quality waters however are found in parts of the shallower zones with nitrates concentrations exceeding drinking water standards.

Sampling and Analytical Methods

Samples were collected in half gallon plastic containers and frozen for storage and delivery to the laboratory. Electrical conductivity, pH, and temperature were determined and samples selected for nutrient analysis were sent to the Department's chemical laboratory in Bryte for analysis. Table 3 lists the methods utilized in the laboratory.

Electrical conductivity (EC) was determined on a Beckman Wheatstone Bridge. Measurements of pH were made using a Hellige comparator with appropriate solution and disk.

EC being related to the total dissolved solids content of a water is usually a good indicator of water quality. It is particularly useful in identification of areas of differing water quality within a producing zone and was used in this study for that purpose.

TABLE 3

Analytical Methods

Parameter	Method*
Chloride	Automated Ferricyanide - AA II
Dissolved Nitrate and Nitrite	Automated Cadmium Reduction Method
Total Ammonia Plus Organic Nitrogen	Semi-automated Block Digester Phenate
Total Phosphorus	Semi-automated Block Digester Ascorbic Acid

*U.S. Environmental Protection Agency. "Methods for Chemical Analysis of Water and Wastes". March 1979.

Chlorides because of their high solubility act as conservative constituents in water and are good indicators of some industrial and domestic wastes. For this reason chlorides were also determined on samples sent to the laboratory for nitrate analysis.

Mineral Quality

As numerous historic and current mineral analyses are available for the deep zone waters in the Chico area, this investigation was directed toward determination of the quality in the shallower zones where the high nitrate levels had been detected.

Shallow Zones (Shallow and Intermediate Zones)

The waters of the shallow zone are vulnerable to increased mineralization from several sources. Recharge from domestic waste systems contains significant additions of dissolved solids to the ground water including nitrogen, phosphorus and chlorides. Urban runoff moving through drainage wells also adds dissolved solids including nutrients and chlorides. Return flows of irrigation water which have been concentrated by evapotranspiration losses also make their contribution.

In the spring of 1983 during phase two of this investigation 49 water samples were collected from shallow wells. During the November sampling, 38 wells were resampled and 24 additional wells were sampled to detect changes and better define the high nitrate areas. Analytical results are presented in Tables 2 and 4. The EC of these bicarbonate type waters range from 138 to 1,300 micromhos per centimeter (umho/cm) with a median of 426 umho/cm. In November the EC ranged from 140 to 1,310 umhos/cm with a median of 495 umhos/cm. Chloride concentrations ranged in the spring from 2 to 70 mg/L with a median value of 16 mg/L, and in November they ranged from 2 to 77 mg/L with a median of 17 mg/L.

The EC of shallow well waters is shown on Figure 10. The spring and November EC values are so similar that they were all used to develop this figure. Although only limited data are available in central Chico, several areas of higher conductivity levels are discernible to the north, west and southwest of Chico. Each contains developed residential areas, is down gradient from urban areas and is essentially unsewered.

As the shallow zone waters have not been monitored historically, there is no basis for determining changes in quality with time or long term trends.

Deep Zone

Waters in the deep zone are generally more uniform and of better quality than those in the shallower zones. Except in the deep zone recharge area to the east (Figure 4) surface waters have limited access to the deep zone. They must move down through the shallow and intermediate zones or through wells that interconnect the surface or near surface waters with the deep zone.
Water quality data provided by the California Water Service Company for waters from 27 deep zone wells from 1982 are summarized in Table 5.

TABLE 4
CHICO NITRATE STUDY
NUTRIENT ANALYSIS

STATE WELL NUMBER	DATE	DISSOLVED NITRATE & NITRITE as N mg/L	TOTAL AMMONIA & ORGANIC NITROGEN as N mg/L	TOTAL PHOSPHORUS as P mg/L
21N/1E- 1G2	5/19/83	2.7	0.0	0.04
	11/30/83	2.6	0.0	0.03
21N/1E- 2C2	5/13/83	5.4	0.0	0.03
	11/30/83	5.5	0.1	0.03
21N/1E- 2F4	5/13/83	16	0.0	0.05
	11/30/83	11	0.0	0.03
21N/1E- 3A3	5/13/83	4.9	0.0	0.04
21N/1E- 3H5	12/ 7/83	15	0.1	0.03
21N/1E- 4G2	5/13/83	4.8	0.0	0.04
	11/30/83	4.6	0.0	0.04
21N/1E- 9G4	5/13/83	6.8	0.1	0.04
	11/30/83	6.9	0.0	0.04
21N/1E-10B1	5/13/83	3.8	0.0	0.05
21N/1E-10B2	11/30/83	2.2	0.0	0.13
22N/1E- 8L1	5/12/83	5.4	0.0	0.05
22N/1E- 8R1	11/22/83	5.4	0.1	0.04
22N/1E- 9G1	2/16/83	6.0	0.1	0.05
22N/1E- 9G2	2/17/83	7.7	0.0	0.06
	11/18/83	8.2	0.1	0.06
22N/1E- 9J2	5/12/83	2.9	0.0	0.08
	11/18/83	3.4	0.0	0.08
22N/1E- 9L1	2/16/83	7.9	0.1	0.05
	11/18/83	8.3	0.0	0.04
22N/1E-10K2	5/19/83	9.4	0.1	0.10
22N/1E-10K3	11/18/83	12	0.1	0.05
22N/1E-10M2	2/16/83	16	0.2	0.12
	11/18/83	10	0.2	0.14
22N/1E-10P1	11/18/83	10	0.1	0.05
22N/1E-13D1	11/18/83	2.2	0.1	0.09
22N/1E-13G3	2/16/83	4.0	0.0	0.02

TABLE 4
CHICO NITRATE STUDY
NUTRIENT ANALYSIS

STATE WELL NUMBER	DATE	DISSOLVED NITRATE & NITRITE as N mg/L	TOTAL AMMONIA & ORGANIC NITROGEN as N mg/L	TOTAL PHOSPHORUS as P mg/L
22N/1E-13G4	11/18/83	9.5	0.1	0.05
22N/1E-14H1	2/16/83	6.4	0.0	0.03
	11/18/83	6.0	0.1	0.02
22N/1E-14K1	12/13/83	17	0.1	0.03
22N/1E-14Q1	5/13/83	12	0.1	0.02
22N/1E-15A1	5/19/83	21	0.2	0.04
	11/18/83	20	0.2	0.03
22N/1E-15C3	2/17/83	16	0.1	0.06
	11/18/83	14	0.1	0.06
22N/1E-15F1	12/13/83	8.9	0.1	0.03
22N/1E-15Q1	12/13/83	7.6	0.0	0.02
22N/1E-16B1	12/13/83	16	0.1	0.05
22N/1E-16E1	11/22/83	0.00	0.1	0.01
22N/1E-16K1	5/12/83	9.1	0.0	0.04
	11/22/83	7.8	0.0	0.04
22N/1E-16G2	11/22/83	14	0.0	0.04
22N/1E-16M1	2/17/83	0.80	0.0	0.04
	--	3.1	0.0	0.05
22N/1E-16R1	12/13/83	4.4	0.1	0.03
22N/1E-17M1	5/12/83	11	0.0	0.06
	11/22/83	7.4	0.1	0.06
22N/1E-17N2	5/12/83	3.4	0.0	0.06
22N/1E-17P1	2/17/83	2.6	0.0	0.05
	11/28/83	3.2	0.0	0.06
22N/1E-20K1	5/12/83	3.0	0.0	0.04
	11/22/83	9.6	0.2	0.04
22N/1E-21F1	2/14/83	0.64	0.1	0.04
22N/1E-21G1	2/14/83	0.21	0.1	0.02
22N/1E-21P1	4/19/83	1.3	0.1	0.05
	11/22/83	2.2	0.1	0.06

TABLE 4

CHICO NITRATE STUDY

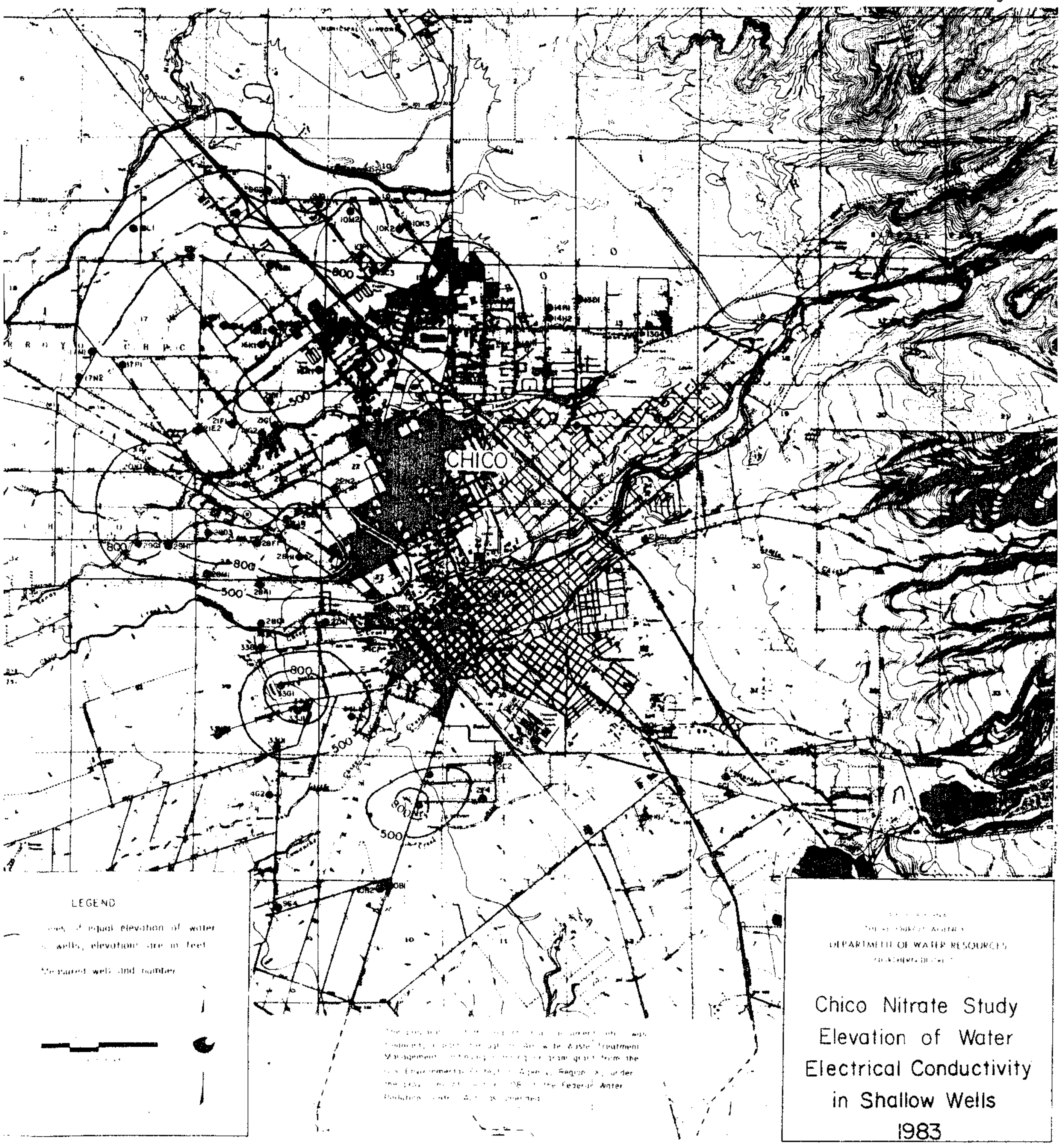
NUTRIENT ANALYSIS

STATE WELL NUMBER	DATE	DISSOLVED NITRATE & NITRITE as N mg/L	TOTAL AMMONIA & ORGANIC NITROGEN as N mg/L	TOTAL PHOSPHORUS as P mg/L
22N/1E-21Q1	12/ 7/83	12	0.1	0.03
22N/1E-22N2	2/14/83	10	0.0	0.03
	11/18/83	10	0.1	0.02
22N/1E-23Q1	5/12/83	5.4	0.2	0.04
	11/18/83	1.8	0.1	0.07
22N/1E-23Q2	11/22/83	2.5	0.0	0.02
22N/1E-25G1	5/19/83	1.8	0.1	0.02
22N/1E-26N1	11/30/83	0.98	0.0	0.03
22N-1E-27L1	5/12/83	3.5	0.0	0.03
	11/22/83	3.8	0.0	0.03
22N/1E-27N1	4/19/83	0.24	0.1	0.04
	11/30/83	0.36	0.0	0.04
22N/1E-28B1	11/18/83	24	0.1	0.03
22N/1E-28B2	11/22/83	7.4	0.0	0.03
22N/1E-28B3	2/17/83	34	0.1	0.07
	11/18/83	37	0.2	0.05
22N/1E-28F1	12/ 7/83	35	0.1	0.04
22N/1E-28H1	5/12/83	14	0.0	0.04
	11/18/83	13	0.2	0.07
22N/1E-28K2	5/11/83	6.3	0.0	0.03
	11/18/83	7.0	0.1	0.03
22N/1E-28M1	5/19/83	0.00	1.6	0.10
	11/22/83	12	0.1	0.04
22N/1E-28Q1	2/17/83	0.47	0.0	0.03
	11/30/83	0.60	0.0	0.03
22N/1E-29G1	12/13/83	27	0.2	0.04
22N/1E-29H1	12/ 7/83	13	0.0	0.03
22N/1E-33B1	12/ 7/83	0.18	1.0	0.04
22N/1E-33G2	2/17/83	16	0.1	0.04
	11/30/83	22	0.1	0.04

TABLE 4
CHICO NITRATE STUDY
NUTRIENT ANALYSIS

STATE WELL NUMBER	DATE	DISSOLVED NITRATE & NITRITE as N mg/L	TOTAL AMMONIA & ORGANIC NITROGEN as N mg/L	TOTAL PHOSPHORUS as P mg/L
22N/1E-33J1	11/30/83	5.7	0.1	0.03
22N/1E-33J2	5/11/83	20	0.1	0.03
	11/30/83	9.6	0.1	0.04
22N/1E-33N1	11/30/83	1.3	0.0	0.04
22N/1E-33Q1	5/13/83	5.6	0.0	0.03
	11/30/83	5.6	0.0	0.03
22N/1E-34C1	12/ 7/83	0.50	0.0	0.02
22N/1E-34L1	2/17/83	3.0	0.0	0.03
	11/30/83	3.2	0.0	0.02
22N/1E-36Q1	5/13/83	0.00	0.0	0.04
	11/30/83	0.00	0.0	0.03

Figure 1(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LEGEND
DEPARTMENT OF WATER RESOURCES
Chico Nitrate Study
Elevation of Water
Electrical Conductivity
in Shallow Wells
1983
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TABLE 5

DEEP ZONE WATER QUALITY

Parameter	Minimum	Maximum	Median
Electrical Conductivity in umhos/cm	210	513	261
Total Dissolved Solids in mg/L	164	330	194
Chloride in mg/L	3	36	10
Sulfate in mg/L	3	12	6
Bicarbonate in mg/L	105	260	138
Nitrate in mg/L	2	40	6

These data show the lower concentrations of dissolved minerals that the deep zone waters contain.

Monitoring data from 41 California Water Service Company wells with 10 or more years of record show only 14 wells with discernible increases in the dissolved solids content of the waters they produce. These data showed increases in EC, chlorides, and nitrates in those well waters. Most of the well waters showing increases are located in the north and northwestern portions of the study area and water levels from these wells indicate less restrictive connection between the deep and shallower zones.

Nitrate Occurrence

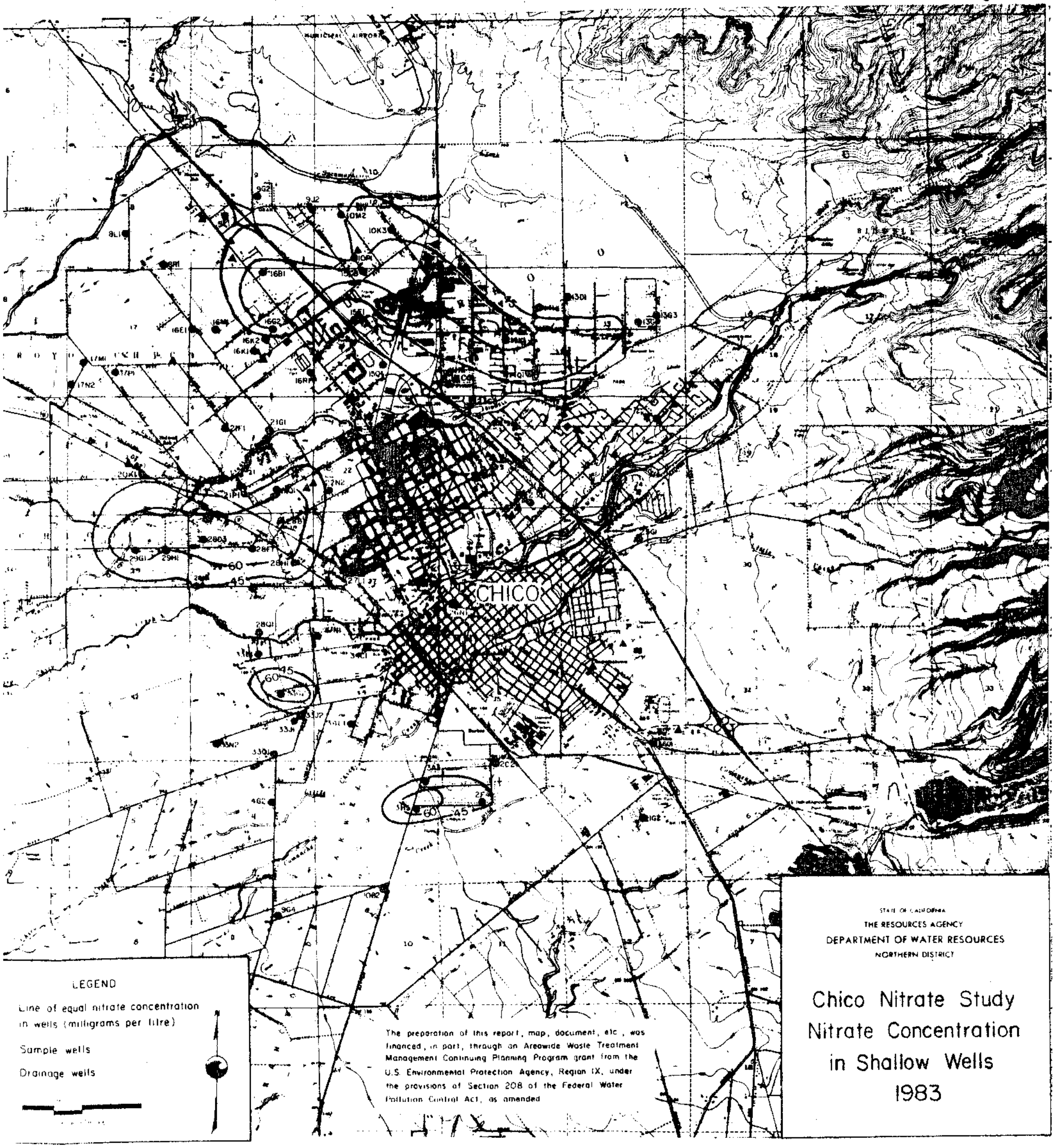
During phase two of this study 43 shallow well waters were sampled and analyzed for nitrates (Tables 2 and 4). Ten contained nitrates in concentrations of 45 mg/L or greater, exceeding recommended drinking water standards. Concentrations ranged from zero to 150 mg/L.

In November, 31 wells were retested and 24 additional wells were located for sampling to better define the areas of high nitrate found in the spring sampling. During this sampling, nitrate concentrations ranged from 0 to 165 mg/L. Results of this sampling are included in Tables 2 and 4.

Data from the two samplings have been combined to develop Figure 11 which shows the areas where high nitrate concentrations were found in the shallow wells.

Although limited data were obtainable for shallow waters under central Chico there are three general areas where high concentrations were found in the study area. Each area contains unsewered residential lands and is located down

Figure 11


LEGEND
Line of equal nitrate concentration in wells (milligrams per litre)
Sample wells
Drainage wells
The preparation of this report, map, document, etc., was financed, in part, through an Areawide Waste Treatment Management Continuing Planning Program grant from the U.S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Chico Nitrate Study
Nitrate Concentration
in Shallow Wells
1983
CHICO

ground water gradient from urban developement and drainage wells. In each of these areas the ground waters also had greater EC values than adjacent areas.

Nitrate Toxicity

Due to the relationship of high nitrates in drinking water to infant methemoglobinemia, a recommended limit of 45 mg/L as nitrate (10 mg/L as nitrogen) was included in the 1962 United States Drinking Water Standards. This same limit has been included by the State of California in domestic water quality regulations.

Although nitrates have been shown to be toxic to both humans and animals, they are generally much less toxic to animals. Nitrate toxicity in humans is generally limited to children less than three months old and effects can range from mild illness to death. There have been cases of nitrate poisoning in adults, but they are rare.

The following information on nitrate toxicity was extracted from the EPA's, 1976 report entitled "Quality Criteria for Water."

In quantities normally found in food or feed, nitrates become toxic only under conditions in which they are, or may be, reduced to nitrites. Otherwise, at "reasonable" concentrations, nitrates are rapidly excreted in the urine. High intake of nitrates constitutes a hazard primarily to warm-blooded animals under conditions that are favorable to their reduction to nitrite. Under certain circumstances, nitrate can be reduced in the gastrointestinal tract to nitrite, which then reaches the bloodstream and reacts directly with hemoglobin to produce methemoglobin, with consequent impairment of oxygen transport.

The reaction of nitrite with hemoglobin can be hazardous in infants under three months of age. Serious and occasionally fatal poisonings in infants have occurred following ingestion of untreated well waters shown to contain nitrate at concentrations greater than 45 mg/L. High nitrate concentrations frequently are found in shallow farm and rural community wells, often as the result of inadequate protection from barnyard drainage or from septic tanks. Approximately 2,000 cases of infant methemoglobinemia have been reported in Europe and North America since 1945; 7 to 8 percent of the affected infants died. Many infants have drunk water in which the nitrate content was greater than 45 mg/L without developing methemoglobinemia. Many public water supplies in the United States contain levels that routinely are in excess of this amount, but only one case of infant methemoglobinemia associated with a public water supply has been reported in the United States. The differences in susceptibility to methemoglobinemia are not yet understood, but appear to be related to a combination of factors including nitrate concentrations, enteric bacteria, and the lower acidity characteristic of the digestive systems of baby mammals. Methemoglobinemia symptoms and other toxic effects were observed when high nitrate well waters containing pathogenic bacteria were fed to laboratory mammals. Conventional water treatment has no significant effect on nitrate removal from water.

Because of the potential risk of methemoglobinemia to bottle-fed infants, and in view of the absence of substantiated physiological effects at nitrate concentrations below 45 mg/L, this level is the criterion for domestic water supplies.

SOURCES OF NITRATE

There are numerous sources of nitrogen within the study area which can contribute to the nitrates found in the ground water. The largest sources are probably domestic wastes, decomposing organic matter, fertilizers, and fixation of atmospheric nitrogen (see Figure 12). There are also processes occurring within the unsaturated zone which are intercepting and keeping nitrogen compounds out of the ground water. The more important of these are uptake by plants in the root zone, ammonia volatilization, and microbial reduction of nitrate and denitrification.

Domestic Wastes

Although much of Chico is sewered and domestic wastes are conveyed out of the study area for treatment, there are large areas on the outskirts of Chico which are not connected to this system. Within these areas domestic wastes are usually treated in septic tanks and discharged through subsurface leach fields. Many areas which are now sewered were occupied prior to the sewering and individual disposal systems existed which probably have and may still add nutrients to the shallow zone waters.

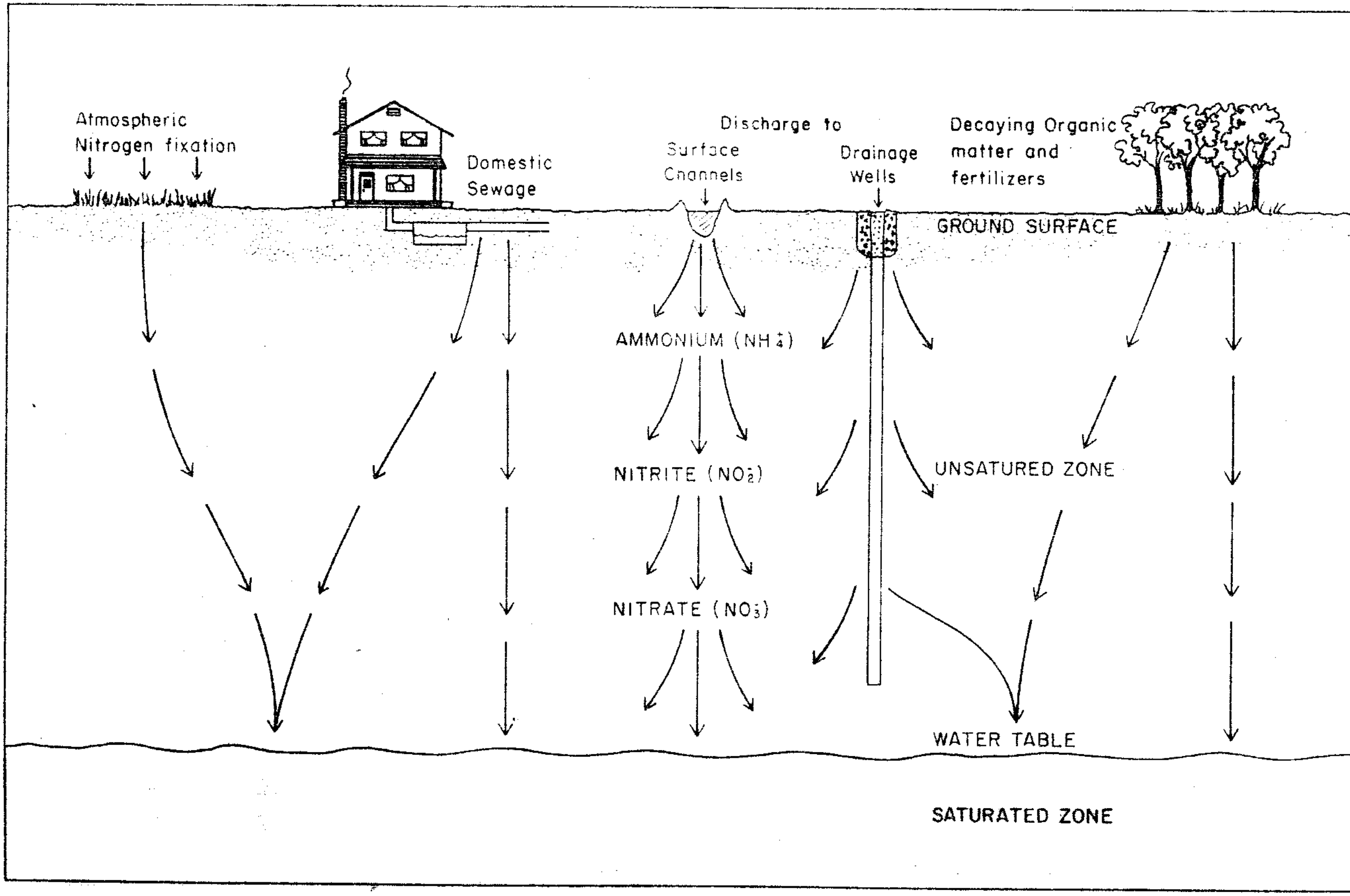
The amount of mineralization of a water supply resulting from its use for domestic purposes varies somewhat with area and mineral content of the water supply. However, studies indicate that the total nitrogen content can be expected to increase by 20 to 40 mg/L. If the nitrogenous compounds are converted to nitrate, the undiluted leachate from this source could contain two to four times the acceptable level for drinking water. Fortunately some nitrogen is usually removed in the unsaturated zone by plant uptake, denitrification, and ammonia volatilization.

Throughout much of the Chico area the shallow ground water table is often less than 20 feet below ground surface, limiting the extent of the unsaturated zone and the nitrogen removal processes. Paving and buildings have covered large areas reducing direct ground water recharge by rain. As rain water contains few dissolved solids and low concentrations of nitrogenous compounds this reduction in recharge results in less dilution of domestic waste effluents.

The point source nature of domestic waste disposal and variations in ground water recharge combine to form receiving waters such as those in the shallow zone which vary greatly in quality (see Figures 10 and 11).

Decomposing Organic Matter

In most areas there are naturally occurring organic materials such as leaves, wood fiber, bark, etc., which are accumulating and decomposing. In the process of decomposition most nutrients are recycled within the soil vegetation system, but some are carried downward to the water table by percolating waters. Organics associated with human habitation such as lawn clippings, bush and tree trimmings, waste paper, etc. are often added to the natural accumulations resulting in greater release and escape of nitrates to ground water.



Nitrate sources to ground water in the Chico area

Figure 17

Surface runoff from municipal and residential areas concentrates some of the organics and transports them into stream channels or drainage wells. Where drainage wells are utilized as they are within the study area (see Figure 11), they provide an avenue for direct movement of nitrogenous materials into the shallow zone or at least entry into the unsaturated zone at a depth below the surface layer of soil. At depth nitrogen recycling and removal processes are usually less efficient and a greater amount of nitrates can be carried into the shallow zone ground waters.

Fertilizers

Most of the fertilizers used on our agricultural crops, lawns, gardens, golf courses, etc. contain nitrogen. The four forms of nitrogen most commonly applied are: nitrate (NO_3), ammonia (NH_3), ammonium (NH_4), and urea ($[NH_2]_2CO$). Some of the nitrogen in these fertilizers is converted to nitrate and carried below the root zone by downward moving irrigation water or precipitation. The form of fertilizer, type of crop, nature of soil, and irrigation practices each influence the loss of nitrates to ground water.

During the past 30 years there has been a dramatic urban expansion in the vicinity of Chico. In the 1950's most of the lands adjacent to Chico were almond or walnut orchards. Other lands were used to grow alfalfa, pasture, grain sorghums, and sugar beets. Since then many of the orchards have been replaced with urban developments but they still remain as the major agricultural land use in the area.

The recommended annual application rates for nitrogen in orchards vary greatly but in the Chico area for almonds they are 100 to 150 pounds per acre and for walnuts 175 to 250 pounds per acre. Most of the field crops except for alfalfa and pasture have application rates that fall within these ranges. However there is probably more variability between individual growers application practices than between recommended applications.

Most of the agricultural lands in the Chico area have loam or sandy loam soils which have medium to high percolation rates making them conducive to loss of nutrients to ground water.

The highest rates of nitrogen use in the study area are for grass turfs on golf courses, athletic fields, parks and a cemetary. In some instances over 500 pounds per acre are used annually. To maintain these turfs, water use is also high and resultant nitrate leaching from these sources has probably contributed to the higher nitrate concentrations found in several locations.

Nitrogen Fixation

Nitrogen fixation is the binding of atmospheric nitrogen into nitrogenous compounds by bacterial action. There are numerous free living bacteria which exist in nearly all soils that fix nitrogen. These bacteria can fix up to 300 pounds of nitrogen per acre annually but generally only fix about six pounds per acre.

Symbiotic nitrogen fixation however by Rhizobium microorganisms in association with leguminous plants usually results in the fixation of several hundred pounds per acre and is a well known source of nitrates. Alfalfa fields and pasture containing legumes such as clover, alfalfa, and vetch are not prevalent in the Chico area but there are several small plots within the study area. While they are probably not a major source of nitrates throughout the study area they may have added significantly to the nitrate concentration locally in the shallow zone.

DISCUSSION OF RESULTS

The water level measurements made in shallow wells during the spring of 1983 and in November 1983 were used to develop ground water contours on Figures 8 and 9. These contours show similar patterns of ground water movement from the recharge areas east of Chico in a westerly and southwesterly direction. Although there was an average lowering of the water table of about 6 feet during the summer and fall, the November contours show neither large pumping depressions or reversals of flow due to heavy extraction or unusual aquifer leakage.

The lowering of the water table is the result of ground water extractions and movement of water out of the shallow zones. Ground water gradients indicate that waters in the shallow zones are moving both westerly and downward.

Nitrate data from the spring sampling showed three general areas where nitrate concentrations exceeded drinking water standards. Within these areas several well waters contained nitrates in excess of 60 mg/L. These areas are located north, west, and southwest of Chico (Figure 11). As no shallow zone wells could be located in central Chico that had well logs or were samplable, nitrate concentrations in that areas are unknown. As that area is served by California Water Service Company wells pumping from the deep zone, it is unlikely that many new wells will be drilled to utilize the shallow zones in that area.

Data from the 31 wells retested for nitrate in November confirmed that there are three general areas of ground water with excessive nitrates and data from the 24 additional wells helped to better define the areal extent of these areas.

A comparison of nitrate data from the two surveys shows remarkably little change in nitrate concentrations. Of the 31 wells retested, 20 showed less than 5 mg/L nitrate change, 5 showed increases ranging up to 53 mg/L and 6 showed decreases ranging up to 47 mg/L. The remarkable consistancy of the analytical results of the two surveys also show excellent reproducibility by the laboratory.

Each of the areas of high nitrate underlies unsewered residential areas and lies in the direction of ground water flow from urban development and drainage wells. In each of these areas there are numerous shallow wells and individual disposal systems which result in the recycling of ground water.

The EC patterns (Figure 10), which appear very similar to the nitrate patterns and indicate buildup of other dissolved salts in the same areas, provide evidence that ground water recycling is occurring in those areas.

Areas west of Chico which do not have excessive nitrates are generally near water-courses where recharge waters provide additional dilution and prevent salt and nitrate concentrations from accumulating to such high levels.

The higher than normal ground water table that existed in the shallow zone during the study period left little of the zone unsaturated. This condition probably minimized the effectiveness of the natural nitrate removal process that operates in the unsaturated zone and may be responsible for some of the higher nitrate concentrations that were detected during the study.

There are no known major point sources of nitrate in the Chico area and the widespread pattern of nitrate occurrence indicates that the major sources are nonpoint in nature. Each of the areas of high nitrate include areas of high residential density which are unsewered. This and the widespread nature of the nitrate problem indicate that domestic wastes are the major source of nitrates in the study area. The location of drainage wells upgradient from the largest concentrations of nitrate indicate that they probably also contribute to the problem. Drainage wells also provide direct access into the shallow zone for other pollutants carried by surface waters.

As hydrologic continuity does exist between zones, increased ground water pumpage from the deep zone would increase the hydraulic gradient within and between zones inducing additional inflow from recharge areas and overlying zones. Fortunately the low vertical transmissivity of the shallower zones in contrast to their higher horizontal transmissivity would limit recharge from that source. However, to protect the deep zone the intermediate zone waters should be kept at as high a quality as possible and wells should not be constructed that will interconnect the deep zone with the shallower zones.

FINDINGS AND CONCLUSIONS

Significant findings and conclusions of this investigation are:

1. There are three water bearing zones beneath the Chico area: shallow, intermediate and deep.

2. Most of Chico receives ground water from the deep zone.

3. In the western outskirts of Chico where the shallow zone is thicker numerous private wells obtain water from that zone and the intermediate zone.

4. The deep zone is recharged mainly in the area east of Chico by the streams that drain the foothills.

5. The shallow zone receives its recharge directly from infiltration of precipitation, stream flow, domestic waste water from leach fields and urban runoff from drainage wells.

6. Ground waters are generally moving westerly in the aquifers and moving downward from the shallow zone to the intermediate zone and from the intermediate zone to the deep zone.

7. The spring 1983 shallower zone water levels were in most areas less than 20 feet below ground surface and by November had lowered about 6 feet.

8. Ground water from the deep zone are generally calcium-magnesium bicarbonate in character and of excellent mineral quality.

9. Ground waters from the shallower zone are generally of good mineral quality but in several locations wells produce poorer quality waters with nitrate concentrations exceeding drinking water standards.

10. In 69 well waters sampled during this investigation nitrate concentrations ranged from zero to 164 mg/L with 21 having concentrations of 45 mg/L or greater. OVER 30% exceed P.H. standards

11. Ground waters of the poorest quality and having the highest nitrate concentrations were generally located in the shallow zone in areas between surface water channels where recharge is minimal.

12. Areas underlain by waters containing excessive nitrates are unsewered and located where they receive ground water moving in from adjacent urban areas where nitrate sources could be additive.

13. Domestic waste and urban runoff are the most widespread nitrate sources in the study area but fertilizers and nitrogen fixation are probably significant contributors in scattered locations.

RECOMMENDATIONS

To ameliorate the nitrate problem that exists in the Chico area and prevent additional impairment of the valuable ground water resources of the area, it is recommended that:

1. An ordinance be adopted that will prevent construction of additional drainage wells. All existing drainage wells should be eliminated as soon as feasible.

2. Unsewered residential areas in the vicinity of Chico be encouraged to connect to the existing sewerage system as soon as feasible. It might be necessary to limit development within these areas.

3. Well construction standards for the area not permit the direct interconnection of the shallower and deep zones by gravel packing or casing perforations. All wells should have appropriate seals.

4. A monitoring program be established for the shallow zone waters to detect changes in quality that may occur due to continued urbanization or improved management practices.

5. Water from wells in or adjacent to the areas containing excessive nitrate concentrations should periodically be analyzed for nitrates. If nitrates exceed the drinking water standard of 45 mg/L, alternate supplies should be used for drinking and cooking purposes.

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